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The WELDING Journal

The Journal of the American Welding Society

Helpful Information on the Use of HAYNES STELLITE TRADE MARK HARD-FACING MATERIALS

MATERIAL	PHYSICAL PROPERTIES	PURPOSES FOR WHICH USED	TECHNIQUE POINTERS FOR APPLICATION	METALS THAT CAN BE SURFACED
HAYNES STELLITE ALLOY No. 1	–red hardness –high abrasion resistance –low coefficient of friction –good corrosion resistance –tensile strength–47,000 lb. per sq. in. –hardness–Rockwell C-54 –coefficient of expansion–similar to steel –hardest of the three grades and most resistant to abrasion.	–For coating surfaces subjected to severe abrasive wear and only slight shock or impact.	***For Steel*** –Remove all rust or scale from surface. –Preheat part to be coated if necessary. –Adjust flame so there is an excess of acetylene. The excess acetylene "feather" should be twice as long as the inner cone. –Bring small surface of base metal to a "sweating" condition, insert end of rod into flame and let rod melt and spread over "sweating" area. –Continue applying until entire surface to be faced is built up to required depth. Do not puddle. ***For Cast Iron*** –Similar to steel except use slightly less excess of acetylene. It is necessary to break up the surface "crust" with end of rod. "Ferro" flux facilitates this operation and is recommended if base metal is dirty.	***Carbon Steels*** up to 0.60 per cent carbon ***High-Carbon Steels*** above 0.60 per cent carbon if properly heat-treated before and after ***Low-Alloy Steels*** heat-treatment may be necessary ***High-Speed Steel*** not recommended ***Manganese Steel*** use electric welding only ***Stainless Steels*** heat-treatment is necessary ***Cast Iron*** easily hard-faced ***Chilled Iron*** on small parts only ***Alloy Cast Iron*** same technique as for gray cast iron ***Monel Metal*** easily hard-faced ***Brass and Bronze*** not recommended ***Copper*** not easy to do ***Aluminum*** cannot be hard-faced ***Hascrome Rod Deposit*** easily faced ***Nitrided Steel*** grind off case before hard-facing
HAYNES STELLITE ALLOY No. 6	–red hardness –high abrasion resistance –low coefficient of friction –good corrosion resistance –tensile strength–105,000 lb. per sq. in. –hardness–Rockwell C-40 –coefficient of expansion–similar to steel –not as hard as, but tougher than, No. 1 or No. 12. Resistance to abrasion slightly less than No. 12. Does not check easily.	–For coating surfaces subjected to abrasive wear accompanied by considerable impact. Also recommended for cutting edges of hot-work dies. Also for valves of all kinds.		
HAYNES STELLITE ALLOY No. 12	–red hardness –high abrasion resistance –low coefficient of friction –good corrosion resistance –tensile strength–76,000 lb. per sq. in. –hardness–Rockwell C-48 –coefficient of expansion–similar to steel –not quite as hard as No. 1 and slightly less abrasion resistant. Stronger and more ductile; more resistant to impact.	–For coating surfaces subjected to severe wear with enough impact to require more toughness than is possessed by No. 1.		
HAYNES STELLITE "93" ALLOY	–high cold hardness –high abrasion resistance –moderate impact resistance –tensile strength–43,040 lb. per sq. in. –hardness–Rockwell C-62 –coefficient of expansion–similar to steel	–For applications where high cold hardness is necessary and corrosion is not an important factor.	–Use flame half way between that for Hascrome rod and that for Haynes Stellite rod. –Applied like Haynes Stellite rod except that mild puddling is permissible on dirty surfaces or for obtaining an extra smooth surface.	
HASCROME ROD	–self-hardening –work-hardening –good abrasion resistance –high impact resistance –tensile strength–40,000 lb. per sq. in. –hardness–Brinell 240 to 500 as deposited depending on application technique. –tougher than Haynes Stellite alloys but not as resistant to abrasion.	–For surfaces subjected to abrasive wear and severe impact. –Makes a very good base for subsequent coating of Haynes Stellite alloys because it resists the mushrooming effect of impact.	–A flame adjustment half way between neutral and that for Haynes Stellite rod is best. –Base metal should be at a "sweating" heat. –Do not puddle. –Use "Ferro" flux if base metal is dirty.	***Manganese Steel*** use electric welding only ***Carbon Steels*** easily applied ***Low Alloy Steels*** heat-treatment may be necessary both before and after ***Alloy Castings*** consider heat-treatment ***Gray Cast Iron*** easily applied
HAYSTELLITE TUBE ROD	–various screen sizes of sharp, irregularly shaped grains contained in tubes of High Test Steel –easily applied by welding flame.	–Where utmost resistance to abrasion is necessary, such as for coating oil well drilling tools.	–Applied in manner similar to other hard-facing rods avoiding deep puddling but obtaining enough penetration to make strongest bond between base metal and binding material.	Same as Haynes Stellite alloys

Send for the free wall chart, "Hard-Facing Materials Data." It includes the above information and other helpful data.

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Preparation of Aluminum Alloy for Spot Welding*

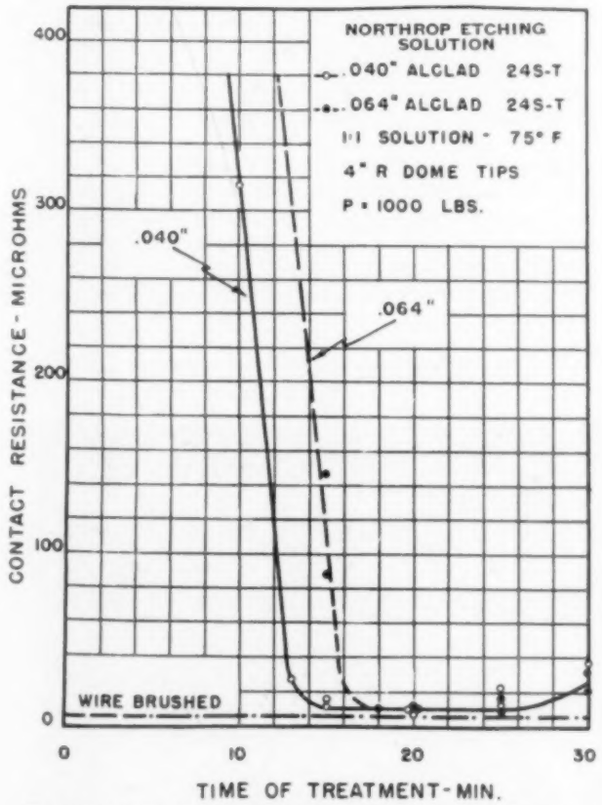
By T. E. Piper†

APPROXIMATELY thirty million spot welds have been made at Northrop Aircraft, Inc., in the past year, and not one hole blown due to an improper surface condition. This figure alone exemplifies the growing use of spot welding in aircraft construction. Where there is growth there is usually advancement, and the exigencies of war make demands for speed in production which bring about the search for methods which will contribute to this aim by using more efficiently the plant we have instead of constructing new buildings. Production should not be thought of in terms of man-hours but rather in terms of what that man in that hour can do. Cleaning and etching of detail parts prior to spot welding has been one of the operations which our company was impatient to accelerate, since the cleaning and etching of detail parts delayed considerably the final assembly and resulted in poor consistency. We have therefore worked out a method which substantially expedites production and at the same time has proved truly superior to older methods under all tests.

It had long been our ambition to spot weld aluminum alloy structures as assemblies taken directly from the jig, put through the cleaning and etching process, and sent to the spot welder, thus eliminating all detail cleaning and etching, and subsequent handling of detail parts before final sub-assembly and spot welding. We have now achieved this ambition, after a year of research and actual employment of this method in the shop. We are satisfied that our method of cleaning and etching spot weld structures as complete assemblies and not in detail

* To be presented at the Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 12 to 15, 1942.

† Process Engineer, Northrop Aircraft, Inc., Hawthorne, Calif.



Resistant Chart Prepared by Rensselaer Polytechnic Institute

Fig. 1—Comparing the Resistance of 0.040-In. and 0.064-In. Aluminum Alclad Material Cleaned and Etched in Northrop Etching Solution with Wire Brushing

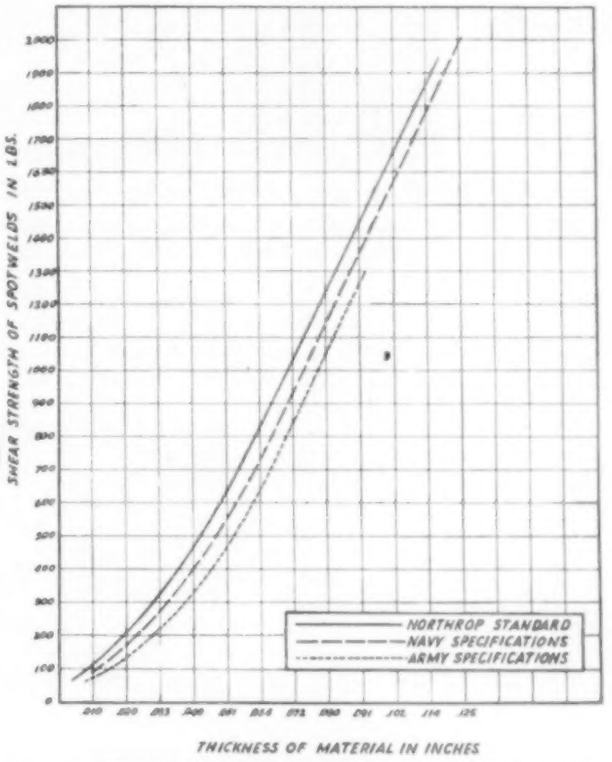


Fig. 2—Illustrating Minimum Spot-Weld Shear Values for 24 STAL

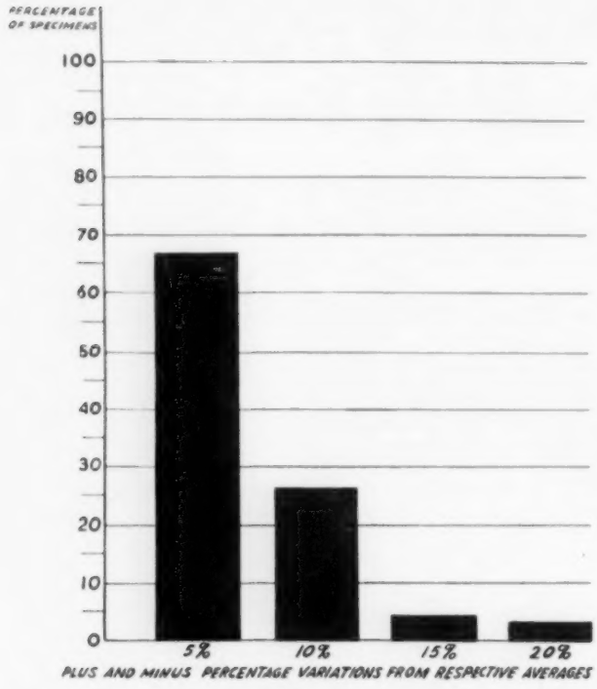


Fig. 3—Percentage of Welds Within the Different Percentages of the Mean Value as Spot Welded

is successful and perfectly safe. This conclusion is based on the following considerations: the faying surfaces or lapped joints are safe from corrosion; there is greater spot-weld consistency and uniformity; and our production has been increased 100%.

There were three reasons for developing new solutions that would etch and clean assembled parts. The first objective was consistency of spot welds. We knew that the hydrofluoric acid solution, which was employed for etching purposes prior to spot welding, was not giving the high percentage of consistency that we required, because of critical etching time necessary to obtain proper etch and because of variables such as the human element, surface condition of the detail parts and the gradual weakening of the hydrofluoric acid bath. Another important factor was the effect of finger marks on the detail parts at time of assembly which promoted unwanted resistance and resulted in inconsistent spot welds.

The second reason for our investigation was the fact that our spot welding was not centralized in a single department. Spot-weld assemblies were being fabricated in different sections of the plant. This required spot-welding equipment for each fabricating division, and also with old cleaning methods necessitated setting six or seven cleaning and etch tanks in each fabricating division, some requiring hot solutions, for the preparation of the aluminum alloys prior to spot welding.

The third reason was that we wanted to accelerate production by cleaning and etching aluminum alloy parts as assemblies and not in detail. With these reasons in mind we set out to find a solution that would fulfil our requirements. All local vendors of such solutions were contacted and asked for a recommended sample solution that would perform this job. After thoroughly testing all samples submitted both in the laboratory and in actual spot-weld production, we chose a solution that satisfied to the greatest extent the three basic requirements. This bath consists of phosphoric acid with a cleaning agent added. It is contained in a lead-lined tank. It has the desired faculty of cleaning and etching parts in one operation and does not require heat. The time of immersion to obtain a properly cleaned surface for spot welding is not critical, thereby lessening the hazard formerly found when using the type of treatment that requires an exact time of immersion for etching purposes. We require from $7\frac{1}{2}$ to 10 min. immersion in this new method. However, immersion over 5 min. above the maximum specified time will not harm the parts or change the spot-welding resistance of the material at the electrode tips. The solution is not corrosive when not thoroughly washed out of faying surfaces or laps. It both cleans and etches in one operation, and thus naturally becomes contaminated with oil, dirt and grease, and therefore requires cleaning after a period of time. We have, however, been using the same bath since September 5, 1941, with weekly additions to replenish the drag-out. Such extended service has been made possible by employing a filtering unit similar in principle to an automobile oil filter in removing the dirt and grease that have accumulated. Since phosphoric acid is more soluble in cold water than in hot water, we require that the rinse-tank be kept at room temperature to facilitate the rinsing of parts. These parts are subsequently dried

Fig. 4—Water Rinsing a Cowl Segment Assembly After Cleaning and Etching

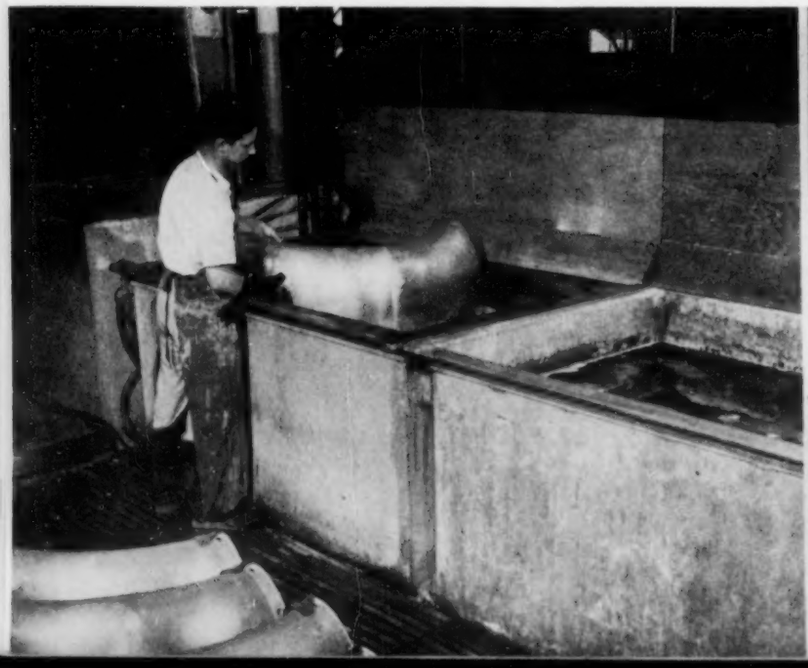


Fig. 5—Air Blast Drying of Cowl Segments After Water Rinse Prior to Spot Welding

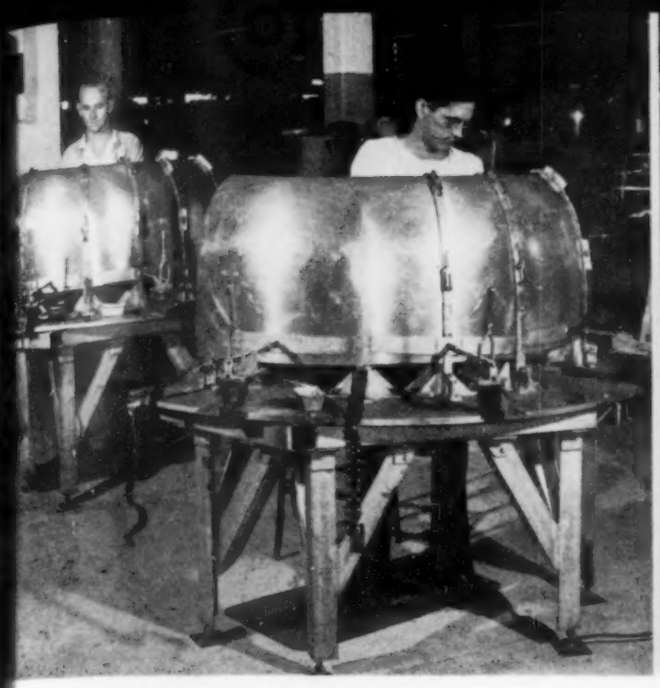


Fig. 6—Assembly of Cowl Segments

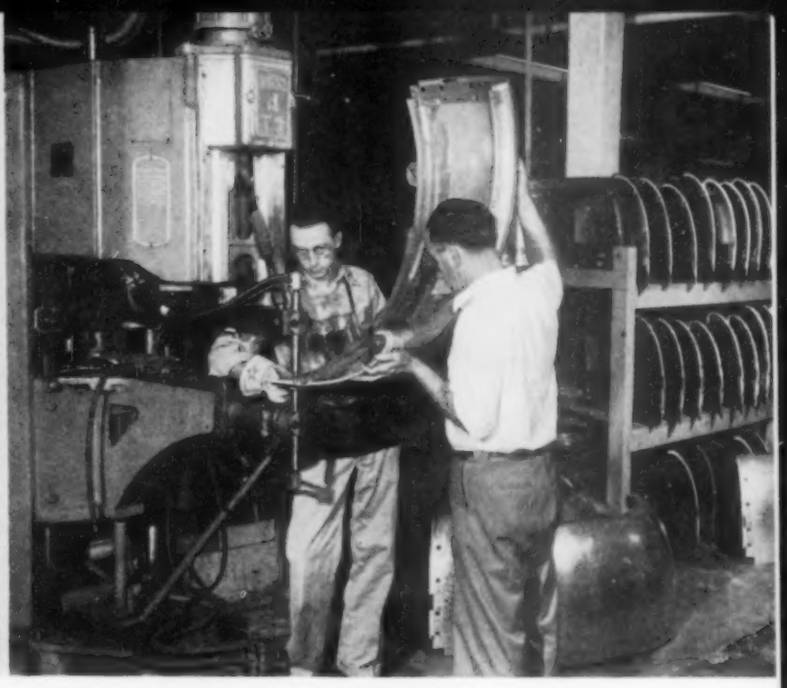


Fig. 7—Spot Welding a Cowl Segment

in an air blast, thereby eliminating hand drying and wiping operations that are customary with most methods of cleaning and etching.

I would like to take you through the process of spot welding a cowling assembly. The cowl is assembled in a jig and held together by Skin-Tights or Cleco fasteners. After removal from the jig it is placed in a stainless steel rack for immersion in the cleaning and etch solution. This rack keeps the aluminum parts from touching the lead liner of the steel tank, thus eliminating the danger of corrosion between the parts and the liner. The convenience of loading parts in a large rack also accelerates production. From the cleaning and etch tank, parts are immersed in a large bath of cold water and, after thorough rinsing are dried by an air blast. Attached to each assembly are setup coupons that follow through with the assembly enabling the setup man to obtain the proper settings on the spot-welding machine, thus eliminating the dangers of the wrong setup and resulting nonuniformity of spot welding.

We are proud of the consistent strength of our spot welds, yet we realize that no two spot welds are exactly alike. You have heard the expression, "As like as two peas in a pod," but we all know this is not accurate, as peas in the same pod are not alike. There is a difference, a variance, however slight, and the same is true with spot welding. No two spots are exactly alike, since there are too many variables that govern the operation of a spot-weld machine. However, we know that by eliminating detail handling of spot-weld assemblies and cleaning and etching the assemblies as assemblies, we reduce our chances of error to a minimum, thereby promoting greater consistency in our work.

A recent investigation was made of spot-weld consistency, using 360 production specimens in thirty-six combinations spot welded on ten different spot-welding machines with the following results:

Variations from Respective Averages	Percentage of Welds
5% of mean	67%
10% of mean	27%
15% of mean	4%
20% of mean	2%

All shear values exceeded Air Corps Specification Requirements.

One of the many advantages of this new spot-weld cleaning and etch solution is its very low surface-tension property which enables it to penetrate and cleanse lapped surfaces of the assembly. An investigation was conducted comparing the new solution with a number of other liquids as follows:

Surface Tension Properties

Material	Specific Gravity	Capillary Raise, Cm.	Surface Tension, Dynes/Sq. Cm.
Water	1.005	8.83	71.8
Recommended alkali solution	1.052	13.9	119.0
Wetting agent (1% Nacconol solution)	1.015	5.75	47.0
Northrop spot-weld solution	1.225	4.15	41.2

Diam. of capillary tube, 0.05 mm.
Temp. of test solutions, 27.5° C.

As stated previously we are cleaning and etching cowl segments after assembly. These segments consist of 17 detail parts. In three shifts, or 24 hr., 125 such segments are spot welded in six machines. Twelve segments are required per airplane. One man per shift handles all the cleaning, etching, washing and drying of aluminum parts to keep 10 spot-welding machines supplied with work. This amount of cleaning and etching would require from 12 to 13 men using the previously recommended solutions and practices as now used by other aircraft companies. The disassembly of the jig assemblies for cleaning and etching and reassembly for spot welding would require approximately as many more men. We estimate that this one department would need 24 more men if conventional spot-welding solutions and methods were followed.

We have made as many as 2000 spot welds on Alclad aluminum etched with our new solution before cleaning the electrode tips. However, this practice is not permitted in shop practice as the tip contours are changed due to forging pressure, necessitating a change in the machine settings to overcome increased resistances that were not present after cleaning the electrode tips to start with. Our shop practice requires cleaning of tips approximately every 200 spots. The time required to

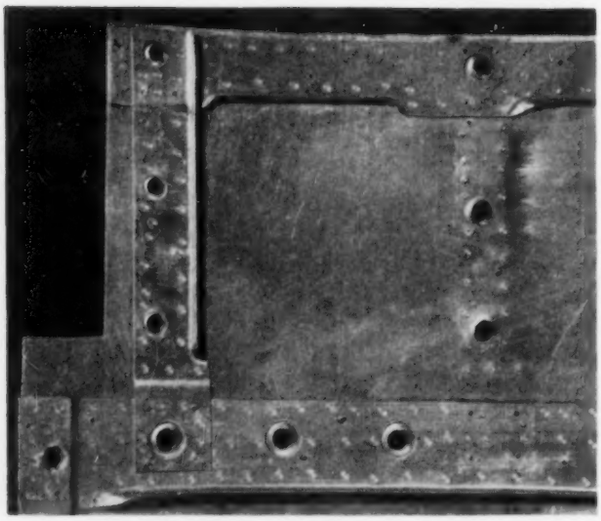


Fig. 8—24ST Alclad Assembly Cleaned and Etched as an Assembly After One Year's Exposure to the Weather. Showing the Absence of Corrosion

Fig. 9—An Aluminum Tail Cone Assembly Being Spot Welded

clean tips is not considered a very serious loss provided that the cleaning equipment is of such a nature that the operation does not require more than a few seconds of a man's time.

Assemblies that were cleaned and etched by this new method and exposed to the weather for over a year have been examined for corrosion in the lapped joints and indicated no trace of corrosion. Lap joints were thoroughly tested for corrosion in our laboratory salt spray chamber prior to adopting this method for shop practice.

We are not interested in the resistance at the electrode tips provided that the resistance is constant for the whole assembly and excess oxides have been removed. Tests have proved this new method to be nearly the equivalent of wire brushing in resistance properties.

In closing we wish to emphasize the proved value of cleaning and etching aluminum alloy assemblies as a unit and not in detail. This method gives much greater spot-weld consistency and obviously accelerates the turning out of planes which is our big aim in these times.

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Distortion and Shrinkage Problems in Ships and Other Large Structures*

Part I—Prevention of Distortion

By LaMotte Grover†

SHIPBUILDERS and other construction forces have done much to improve control of distortion in welded construction and to develop methods of oxyacetylene flame straightening for removing distortion; but there are quite wide variations in practices employed and their effectiveness. So many influential factors are involved that it is difficult to evaluate each one in routine production. Some research in these problems has been done and the results, together with obvious results of experience in production, make it possible to draw a good many conclusions as to the most effective practices.

From quite a broad survey of methods used and results achieved in various shipyards and steel fabricating shops, it has been possible to formulate a number of general principles that can be applied in the control and correction of distortion. In most cases the results of this practical experience can be explained on the basis of well-known physical properties of steel and its behavior under changes in temperature, so that results can be predicted under varying circumstances. In other cases, some of which will be described later, the explanation is not so obvious and research is needed to answer some of the questions that are uppermost in the minds of those who are trying to work out these problems efficiently on the job, and thereby to facilitate rapid, economical production, and to conserve strategic materials such as welding electrodes, oxygen and steel.

Objections to Distortion

The most obvious objection to distortion, and often the only legitimate one, is from the standpoint of appearance, as in a ship's superstructure or shell plating. The local supervisors and inspectors of workmanship can make it easier or more difficult for the shipbuilders, depending upon the degree of judgment that they exercise, bearing in mind that riveted construction is not wholly devoid of distortions, although they are less obvious because of surfaces being broken up by rivet heads, over-lapped edges, butt straps, etc. Most officials in responsible charge of determining general standards of workmanship in this regard, recognize that in times of war good appearance is decidedly secondary in importance to speed of construction; but there is still quite a variation in the requirements imposed by local inspectors.

Aside from detracting from good appearance, distortion may, in some cases, be objectionable from a technical standpoint, and in extreme cases, may impair the usefulness of a structure.

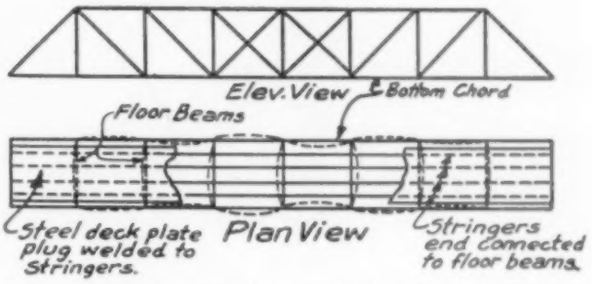


Fig. 1—Cumulative Shrinkage in Deck of Highway Bridge, Resulting from Improper Welding Sequence, Caused Bowing of Floor Beams and Buckling of Bottom Chord Tension Members

For example, about 8 years ago, one of the state highway departments was constructing a welded steel-plate deck on a three-span truss bridge. The sequence of making the various welded joints between the members and to join the plating to the stringer beams, was such as to result in an accumulation of distortion as the work progressed from one end of a span to the other. This caused the floor beams to bow quite badly (Fig. 1). The sequence was then changed for one of the remaining spans, so that both end panels of the deck were welded up rigidly at the start, and the welding progression was carried from both ends toward the center. The sequence still did not provide for relief of cumulative distortion. As a result, the restrained shrinkage of the deck caused such high compressive stresses in the bottom chord main tension members of the bridge on either side of the deck, that these chord members buckled seriously, as much as 4 in. outward in a length of 12 feet.

With the subassembly method of production as used in shipbuilding, there is not much likelihood of an occurrence of this kind, and most shipbuilders have used welding long enough to know how to avoid such difficulties.

When plating is badly buckled between deck beams of a transversely framed ship, and reliance is placed upon this plating to carry compressive stresses resulting from sagging of the ship in a seaway, it is logical to believe that the resulting eccentricities would reduce the strength of the hull somewhat.

One of the most troublesome occurrences of distortion is in the sole plates or bearing areas of stools and foundations for machinery or shafting, where extra machining is required as a result; or often very extensive additional grinding to provide bearing surfaces within the very strict tolerances that are usually imposed.

* To be presented at the Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 12 to 15, 1942.

† Structural Welding Engineer, Air Reduction Sales Company, New York, N. Y.

Fig. 2—Flat Plate Platens or Slabs, with Holes and Slots for Dogs, Eliminate Tack Welding Dogs to Platens and Chipping to Remove Tack Welds

Excessive distortion in decks and bulkheads may cause serious delay in subsequent fitting-out operations because the decks must be faired for the installation of machinery, fittings, etc., and the bulkheads must be faired ahead of the joiner work.

These examples will serve to illustrate the importance of controlling distortion as much as possible and using speedy and economical procedures to remove distortion where it occurs.

Most structural elements in bridges and buildings have more inherent stiffness, especially around their boundaries, than plate construction. However, the controlling of distortion in light plating forming parts of a ship's superstructure, has its counterpart in other steel fabricating industries, such as the production of light rectangular tanks and containers for various liquids, steam-generating plants, industrial washing units and countless other kinds of welded assemblies.

It is evident that distortion control is in no way a problem peculiar to shipbuilding, and also, that the fundamental problems and difficulties involved in controlling distortion are virtually identical in nearly all fields of welded construction. With this in mind, the remainder of this paper will be centered principally around welding in the shipbuilding industry.

Causes of Distortion

Although welding is the chief offender in causing distortion, it is often blamed for more than its due share. Distortions in evidence in a completed hull after launching and installation of machinery and various gear, have been traced to the following origins, listed chronologically, all of which occur frequently enough to be worthy of note:

1. Rolling stresses in the steel material and their direction relative to the location of welds; also cold working stresses.
2. Kinks, knuckles and permanent bends due to rough handling of plates and shapes and improper support for them during handling and storage before fabrication.
3. Distortions resulting from improper support or from other adverse conditions during gas cutting; also bow or camber in plate edges resulting from shearing or from improper setting of joggling rolls.
4. Distortions locked up in welded assemblies because they are supported in a distorted condition during welding.
5. Non-uniform linear shrinkage and angular distortions during fabrication welding, which is much worse when the welds are oversize.
6. Damage of the kind mentioned in item no. 2, occurring during transportation, storage and erection of bulkheads, deck sections and other assemblies.
7. Distortions resulting from forcing a fit-up, or arising in some other manner from fabrication or mold loft errors and inaccuracies, or from inaccurate trimming or lining by shipfitters.
8. Non-uniform shrinkage during erection welding.
9. Buckling under gravity loads which were not anticipated in design. (For example, non-structural bulkheads assumed to act only as partitions, often sustain very appreciable loads because of their position and the structural arrangement around them, and because their boundaries are welded to the deck heads before parts of the ship above have been erected and before the decks have deflected under these loads.) Welding distortion may start such buckling, causing eccentricities which become greater under external loading of the distorted panels.
10. Unequal expansion of different parts of a structure resulting from changes in atmospheric temperature or from the heat of the sun's rays. Distortions observed in decks often disappear after the decks have been covered with wood planking which shields them from the sun.
11. Axial loads (in the plane of the plating) on decks and bulkheads, resulting from the shrinkage of other adjacent parts of the ship's structure during welding of these adjacent parts, or when they are overshrunk during flame straightening. Such overshrinkage can also cause distortions in adjacent parts by pulling them out of line laterally and in other ways.
12. Shrinkage resulting from the welding of cargo

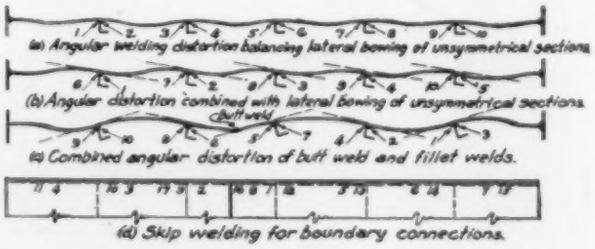

(a) Angular welding distortion balancing lateral bowing of unsymmetrical sections
(b) Angular distortion combined with lateral bowing of unsymmetrical sections
(butt weld)
(c) Combined angular distortion of butt weld and fillet welds.
(d) Skip welding for boundary connections.

Fig. 3

handling gear, fittings and other appendages to decks and bulkheads.

Instances have been noted in several shipyards, where parts of a ship's structure have likely been designed adequately for the loads to be carried but not adequately for deflection. Where exceptionally shallow beams are used, to provide clearance desired in public rooms, consideration should be given to deflections as well as strength.

Some of the worst distortions in decks and bulkheads occur quite a while after all welding in the vicinity has been completed, sometimes as much as two months afterward, although such occurrences cannot be called commonplace. The causes of distortion and bucklings are not always a matter of the effects of local weld shrinkage. The cause may lie partly in design or in many other construction operations, and control must be exercised all along the line of production operations, to eliminate distortion successfully. To eliminate or prevent distortion at any point, it is first necessary to determine the cause of the distortion, as accurately as possible, and the manner in which it has occurred.

Shrinkage and Distortion of Welding

There is much more tendency toward distortion in some types of vessels than in others, largely because of differences in weight of plating, amount of welding and structural framing systems.

Buckling caused by shrinkage of welding is largely of the same nature as buckling in slender columns under load. Thin plating is weak in column action as well as in bending resistance and it does not have as high a resistance to expansion, contraction and angular distortion stresses, all of which increase with the amount of welding.

In solving a distortion problem it is desirable to differentiate between the effects of longitudinal and transverse contraction and angular distortion and to know something about the relative amounts of each that are involved. In welded deck or bulkhead assemblies with beams, stiffeners and seams all running in the same direction, angular distortion occurs at both fillet welds and butt welds. When the latter are not strong backed they are one of the major causes of buckling, which, as a result, will often bulge one panel out and the next one in, etc., as in Fig. 3 (*c*), an action similar to deflections in a series of continuous spans of a bridge due to bending applied in only one span. The sequence of welding shown in Fig. 3 (*a*) seems to be best because it balances the angular distortion effect if weld (1) is not completed too far ahead of weld (2), etc. In Fig. 3 (*c*) the consecutive welds (1) and (2) both contribute to the in-and-out type of buckling illustrated.

In such assemblies the longitudinal contraction along the stiffeners or beams leaves slack in the plating along the middle of the panel.

Transverse shrinkage at the welds will tend to shorten the assembly uniformly, without distortion, except that heavier welding at beam and stiffener ends causes more shrinkage there, or, if the welding is not carried clear to the edges of the plating, the edges are not shrunk and the slack left in them will cause a wavy edge. This effect may be increased by the shrinkage phenomenon illustrated in Figs. 1 (*c*) and (*d*) on page 1082 of the 1942 *A.W.S. Handbook*, which effect produces compression at the plate edges.

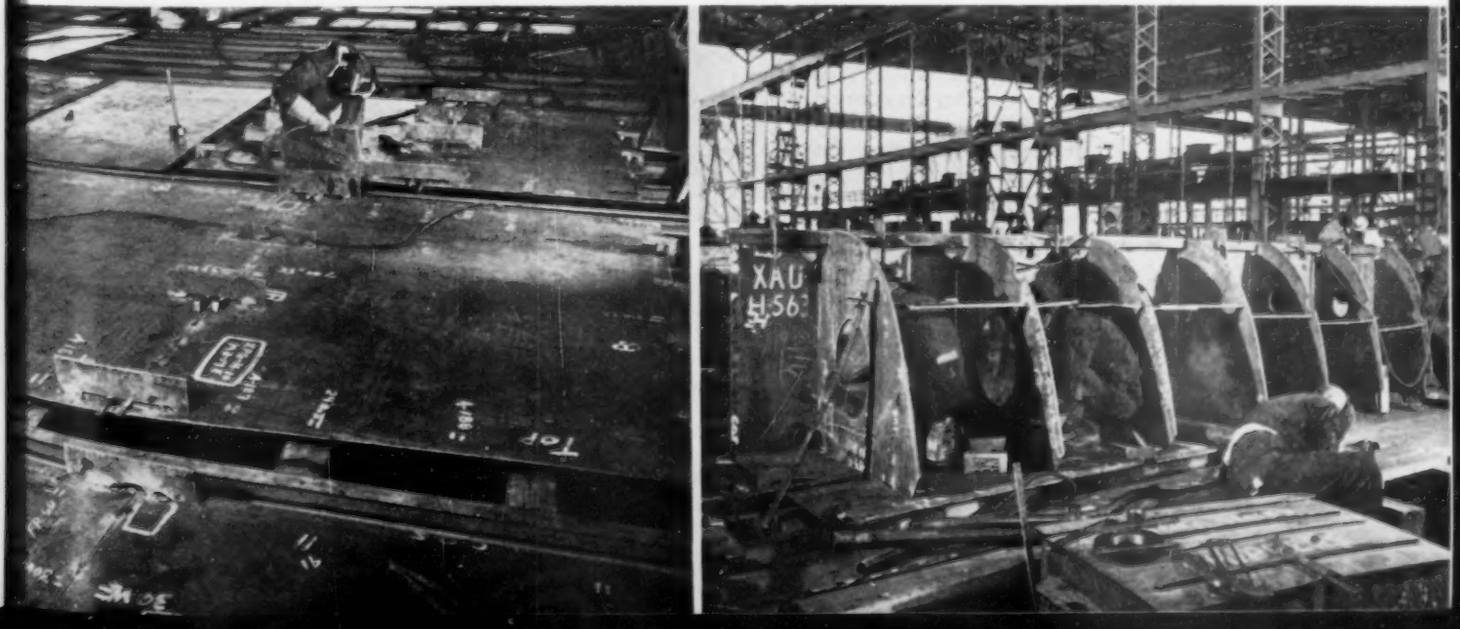
All of these effects can be reduced greatly by dogging down plate edges to welding floors or platens (Figs. 2 and 4), or by weighting down the assembly to hold it fair during welding so that shrinkage will be absorbed while the welds and adjacent metal are in the hot plastic stage.

The field welding of boundaries of bulkheads and deck sections results in a longitudinal shrinkage or shortening of the boundary edges, which leaves slack in mid-portions. Skip welding as illustrated in Fig. 3 (*d*) has been found very effective in reducing the amount of such contraction.

It is best to wait to make cut-outs in edges of bulkheads to permit deck beams to pass through, until all platen welding has been done on the bulkhead and its edges are being trimmed. Cut-outs for doors, port holes, etc., remove stiffness locally and invite a concentration of buckling in way of such openings.

For other data on shrinkage distortion, the reader is referred to the Appendix of Chapter 32B, page 1092 of the 1942 *A.W.S. Handbook*. This information has been developed through research and confirmed by experience.

Fig. 4—Open Beam-Type Welding Platforms Permit Dogging Only at Beams. Note Temporary Stiffener Clamped Along Free Edge of Vertical Keel (Right)



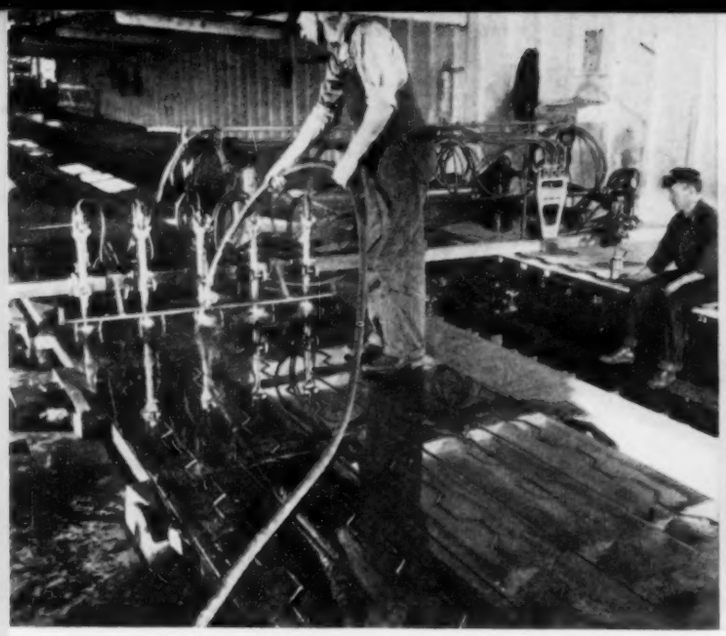


Fig. 5—Water Quench, Following Gas Cutting for Splitting Channels to Make Serrated Stiffeners or Deck Beams, Used to Eliminate Distortion

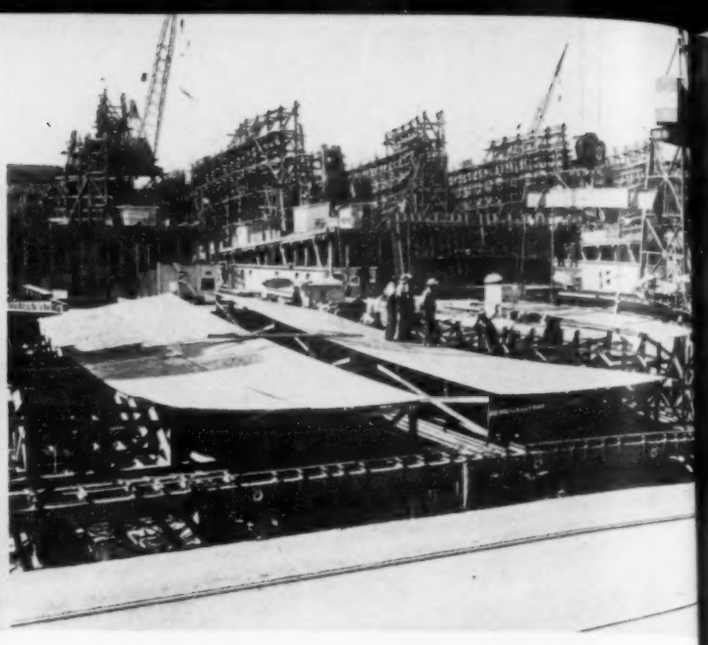


Fig. 6—Warped Molds or Welding Platforms Are Used for Bottom and Side Shell Subassemblies

General Methods of Controlling Distortion

The methods of correction for many of the causes of distortion that have been enumerated are obvious. Often it is largely a matter of providing adequate supervision over all operations to eliminate carelessness or neglect which may save a few minutes in some operations, such as handling and storing of material and assembles (Fig. 8), or lining, trimming and fitting, at the expense of many hours' delay or extra work in subsequent operations such as welding and flame straightening.

The principal methods of distortion control in welding have been well summed up in the "Report on Thermal Stresses and Shrinkage in Welded Ship Construction" by the A.W.S. Committee on Welding in Marine Construction, as (*a*) prespringing or initial distortion (Fig. 10), (*b*) strongbacks and jig methods, (*c*) drum heading, (*d*) extent of tacking and wandering sequence and (*e*) design. To these might be added the rate of heat input and dissipation as affected by the details of the welding procedure and the providing of a mass of metal, or other means for conducting away the heat of welding.

A number of shipyards have come to a very extensive use of wood ribbands, usually 8 x 8 in. for large sections of decks and bulkheads and smaller sizes for lighter bulkheads, installed across stiffeners or deck beams during fitting and tacking operations on the platens (Fig. 8). Sometimes heavy steel bars, rails or steel beams, when they are available, are used in lieu of ribbands. If attached on the smooth side of the plating after the assembly has been turned over for completion of butt-welded seams, they are effective in holding the plating fair during erection welding. The chief function of these ribbands, however, is to protect the assemblies from damage during handling, storage, transportation and erection, and their use has proved to be very well worth while. Once installed, these ribbands or temporary stiffeners should be left in place until erection welding is completed and until any obvious or pronounced buckles have been removed by flame straightening, so that they will serve in the fullest capacity.

For the general run of work, it is not often deemed practical to remove mill stresses prior to fabrication, although they are quite troublesome at times. Lightweight plating is sometimes mangled or stretcher leveled when it is received in a badly warped condition.

A practice that is followed to some extent in reducing distortion during gas cutting of mild steel is to follow the cutting tip with a jet of water, as in the case of splitting a channel along a joggled line to form two serrated beams or stiffeners (Fig. 5). Rolling-mill stresses cause a large part of the distortion that is experienced in splitting beams.

The most important generally applicable precautions to be taken against welding distortion during construction are:

1. Avoid oversize welds and more welding than is required.
2. Provide proper support for welded assemblies, and devices to hold them straight or fair during welding, with plate edges dogged down.
3. Distribute the heat of welding by using a suitable sequence, so that expansion or contraction will not be built up locally to so much greater extent than in other parts of the assembly, that the inherent stiffness of the assembly will not be sufficient to resist the distortion forces.
4. Use the size and type of electrode, welding current and welding speed and other details of welding procedure that will result in the least distortion for the thickness of metal and local stiffness of the assembly involved.

Restraint and Plastic Yielding

The matter of "stress free" welding *vs.* welding under restraint still remains a controversial subject as evidenced by opinions held by welding engineers and superintendents in various shipyards. The main reason for this controversy has been an attempt to generalize too broadly. Extreme rigidity causing restraint over an entire structure or large assembly, which results in a large accumulation of shrinkage, can cause serious results as described in the case of the highway bridge mentioned previously.

However, a considerable amount of local restraint is usually considered indispensable in controlling distortion. Stress measurements made on a number of welded

bridges in Germany have indicated that higher residual stresses resulted when distortion occurred in parts of those bridges, adjacent to butt welds, than when the distortion was restrained and the shrinkage was absorbed by plastic yielding in the hot metal in and adjacent to the welds. There may be even less residual stress near a strong-backed butt weld which has yielded plastically during cooling than would exist if strongbacks were omitted.

Any one who doubts that welding shrinkage can be absorbed by hot plastic metal, needs only to deposit a weld between two pieces, as a heavy tack weld between a stiffener and a plate, and then to see how easily the stiffener can be rocked to square it with the plate, as long as the weld remains at a red or yellow heat.

Adequate tack welding of an assembly in advance, and the use of a wandering or skip sequence of welding provide partial local restraint which is beneficial, because weld increments already cooled enough to have rigidity act to hold the parts in proper position, thus breaking up and relieving the local cumulative distortion that accompanies progressive welding along a joint. Some fabricators have used hot peening or vibrating along a welded joint to assist in forcing a more complete absorption of shrinkage by plastic deformation.

The dogging down of plate edges and weighting down at intermediate points, and strongbacking across butt welds in plating are other examples of partial local restraint used most effectively to combat distortion by forcing local, hot, plastic yielding.

In each case, the amount of shrinkage and the general stiffness of the assembly and its parts must be taken into consideration, as well as the size or extent of the portion being restrained, but it is seldom that ordinary restraining provisions made to control distortion in subassemblies, can result in cracked welds or other serious difficulties.

A mistake often made in installing strongbacks is to make them too short to be effective. Also when temporary intercostal bars or angles (sometimes called "headers") are installed across panels between stiffeners to provide stiffness, they are often left free ended, whereas light tack welding of their ends to stiffeners would prevent angular distortion at the stiffener welds and would also provide very desirable stiffness to prevent kinking of the assembly during handling.

An expedient used by some shipyards is to omit certain welds on subassemblies near free unsupported edges or at other locations where there is no self-contained rigidity to resist distortion, and to wait to make these welds until erection when other parts of the ship will furnish the needed restraint against distortion.

If butt welds in plating are not made until stiffeners or deck beams across these welds have been tacked in place, these members will act as strongbacks. An alternative is to weight down the plating along the seams during welding. There is the further alternative of "drum heading" very light plating by tack welding it down along the edges to flat plate platens. A few shipyards tack the plating down before any welding is done on it. The more common practice is to first fit and tack stiffeners or beams, and make all butt-welded seams in the plating (except backing runs), then to tack weld the boundaries down to the platens with about 3-in. welds at 12-in. centers and finally to finish weld the stiffeners or beams to the plating. Even with this procedure, the shrinkage is so great that many of the tacks to the platen break and they are replaced immediately.

On the other side of the question regarding "stress-free-welding" *vs.* restraint, it must be said that a number

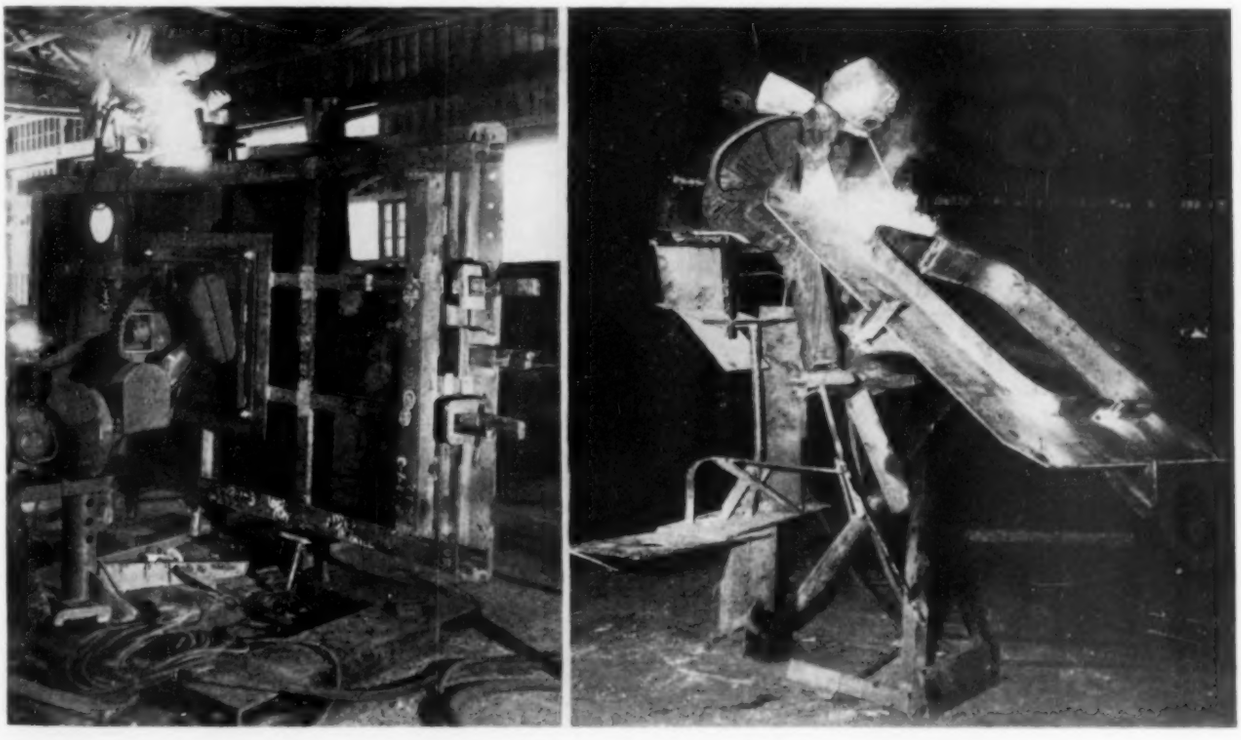


Fig. 7—Down-Hand Welding, Facilitated by the Use of Jigs and Positioners, Permits Use of Welding Procedures That Reduce Distortion. Note Inexpensive Positioning Device, Made from Scrap, for Welding Pipe Tunnel Frames (Right)

of shipyards still adhere more or less to principles of stress-free-welding, and one of the largest welding fabricators in this country, who pioneered in the field and has had many years of experience, still adheres quite generally to stress-free-welding for even rather small assemblies, with most excellent results. Special temporary alignment and connection devices called "key plates" and "key shims" are employed which resist distortion effectively but offer a comparatively small amount of restraint directly opposed to the major transverse weld shrinkage. Plating is usually trimmed about one-sixteenth inch oversize to allow for shrinkage at butt welds, the extra length or slack being taken up during fitting by furring up the plate between the seams to be butt welded. With the use of these expedients, tack welding is largely if not entirely eliminated.

Platens, Jigs, Fitting and Clamping Devices

It should not be necessary to state that a fundamental requirement for avoiding distortion is the provision of substantial welding platforms or platens and jigs to provide adequate support for the work and hold it fair (or in a presprung condition when necessary) during welding. A very marked correlation can be observed in the various shipyards between the lack of such facilities for support and clamping during welding and the amount of flame straightening required to remove distortion and buckling.

In addition to reducing the actual shrinkage of the welds and adjacent base metal, the provision of proper support and clamping or stiffening prevents temporary warping during welding which would otherwise be locked into the assembly by subsequently made welds.

Welding floors or platens of several types are in common use. Solid flat plate platens to which dogs can be tached wherever they are desired have the further advantage of preventing workmen from falling through them. Also, the mass of plating conducts heats away and helps to prevent overheating locally. Tack welds must be chipped flush after each use but some shipyards and fabricating plants have overcome this disadvantage by providing holes or slots to hold the dogs (Fig. 2). Pin dogs will hold in slabs as thin as $^3/_4$ or 1 in.

When open rail or beam platforms are used, plate edges can be dogged or clamped down only at the rails or beams (Fig. 4), which are usually at about 24- or 30-in. centers, supported by caps or sills at 6 to 10-ft. centers, for supporting bulkheads, decks and inner-bottom assemblies. Warped platforms or molds (Fig. 6) are provided by some yards for fitting and welding side shell and frame assemblies and others that are not flat.

The extra cost of providing good foundations for platens or welding platforms is much less than the cost of occasionally tearing them up and relaying them when they settle, besides assuring proper support throughout the life of these facilities.

Heavy weight boxes of 1000 lb. or more, filled with concrete or punchings, or bundles of rails, are often set directly on the plating of an assembly or on deck beams or stiffeners or on temporary strongbacks laid along the welds. The handling of such weights sometimes ties up a crane that is needed elsewhere. At plate edges the use of dogs is more expedient.

Substantial jigs for fitting and tacking and for final welding are justified when there is a large amount of duplication, as in the yards building large orders of Liberty Ships. Hatches, heavy deck beams and girders, solid floors with flange-rings in lightening holes and with vertical stiffeners are commonly clamped in such jigs to prevent distortion during welding. Jigs are sometimes mounted upon trunnions or on positioners (Fig. 7). One Great Lakes fabricator has provided a very large tilting jig to accommodate inner bottom assemblies of the full breadth of a ship. Down-hand welding is done with a higher rate of heat input and consequently less distortion in most cases, as well as at a lower cost and more rapidly. Where expensive jigs are not warranted, improvised racks supported by A-frames can be used to position work.

Temporary stiffening channels or angles held in place by wedges and C-clamps or by driven clips are effective in preventing distortion of free edges that cannot be dogged down to platens (Fig. 4). Sometimes two similar parts, such as T-beams, can be clamped together back to back so they will provide mutual restraint one against the other to prevent buckling of free edges, flanges, etc.

A mistake often made in using saddles or yokes and wedges to draw heavy beams, ribbands or frames up to plating in fitting, is to use too few saddles, or saddles with legs too far apart. This results in distortion or dents in the plating where the saddles have pulled on it, which distortions are costly to remove.

Much of the general warping distortion in bulkheads and decks starts from angular distortion at butt welds in the plating and extends into several panels in both directions, in the same way that general distortion can result from a neglect to dog down plate edges during welding. Two types of strongbacks for buttwelds are illustrated in Fig. 4, and an articulated type that requires no tack welding is shown in Fig. 10. These butt-weld strongbacks should be about $^1/_2$ x 4 to 6 in. and at least 20 in. in length. When installed on the open side of the V-groove they must be tacked to the plating at the groove edges as well as at their outer ends. When the butt joint is near a beam or stiffener the end of the strongback should be butted against the web of the beam or stiffener and tacked to it. Strongbacks are spaced at 24 to 36-in. centers along butt joints that are not stiffened by other elements of the structure.

Inaccurate preparation of material and trimming of welded assemblies results in poor fit-up and oversize welds which increase distortion tendencies greatly. Forcing a good fit-up between inaccurately trimmed parts often causes distortion. Inaccurate knuckling or bending, such as that for providing camber in deck plating, makes it difficult to hold the plating fair across butt welds and starts angular distortion which creates an eccentricity for the forces of lateral contraction during welding. Occasionally, this results in the joint rising rather than sinking as it would under only the influence of angular weld distortion.

An expedient commonly used to reduce distortion in welding very light plating for containers, wrapper plates, housings, etc., is the providing of some medium for conducting away the welding heat so it will not accumulate locally. Partial immersion in water, wet rags or burlap, and dry ice close to the edge of the joint, have been used, but a more common method is to provide heavy steel or copper backing bars or clamping devices of considerable mass, usually a part of the welding jig and sometimes water cooled. In heavier material, especially, it would be possible to overdo this kind of rapid cooling to the point where the welded joint would be hardened to an objectionable extent. Such methods are not used very much at present in shipyards.

For most fitting, quick acting devices involving wedges, cams, levers, eccentrics, etc., are better than slow acting devices using bolts or screws. There are many places, however, where parts must be pulled together rather slowly and a large force is required. A most useful tool

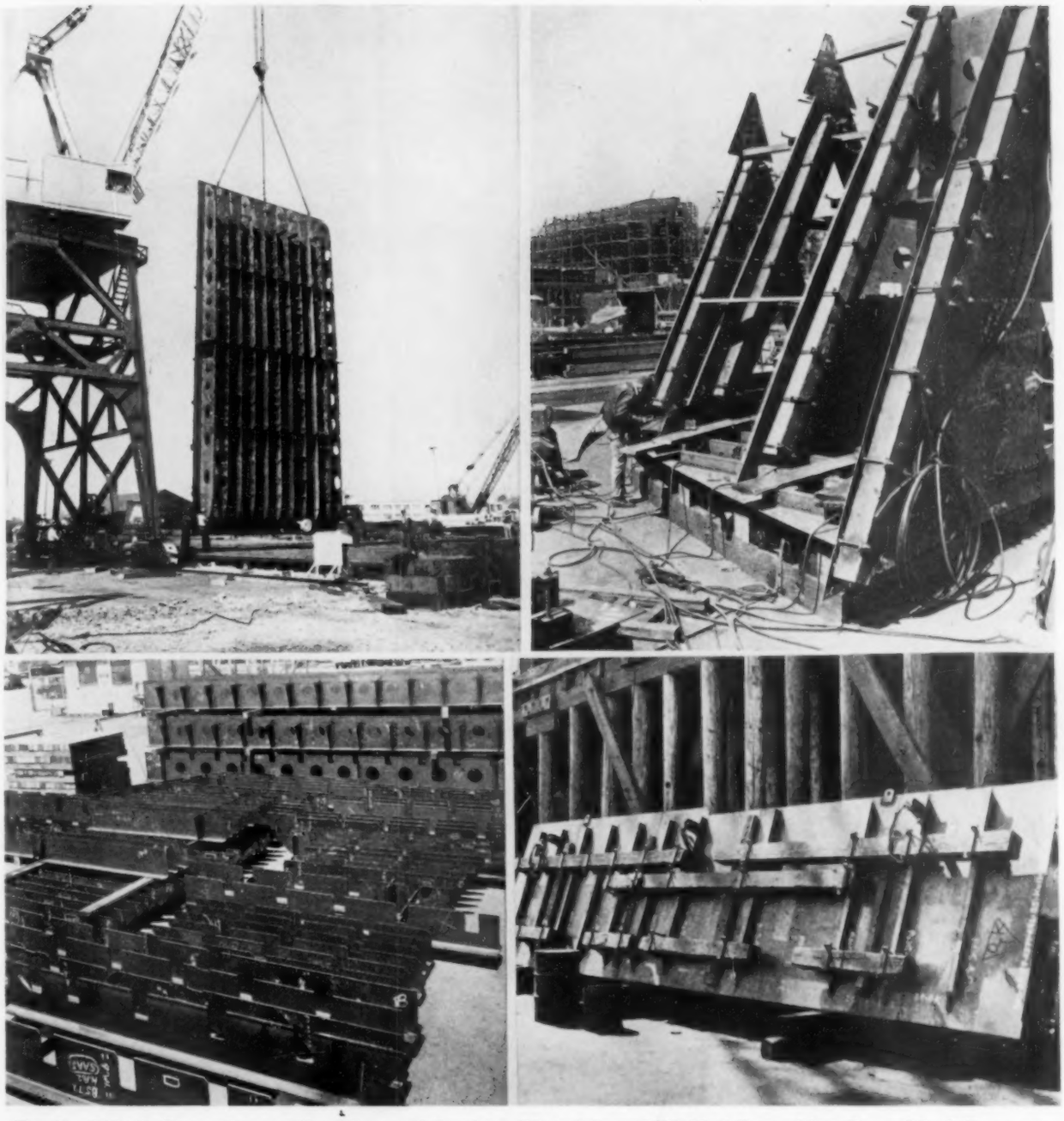


Fig. 8—A Little Extra Care in Handling and Stacking Materials and Welded Assemblies Saves Much Expense in Subsequent Operations. Note Use of Heavy Wood Ribbands

for this purpose is the push-pull jack shown in Fig. 9.

It is important to realize that it is not just the pronounced kinks or buckles, observed during welding on the platens, which cause trouble. Bulkheads or deck sections that have not been supported and dogged down properly during welding may not look bad while they are lying free, but they usually have long winds or warps, even though no sharp buckles are apparent. Then when they are lined and fitted during erection the buckles show up, before erection welding is done. The importance of good, fair welding platforms or platens on foundations that will not settle cannot be stressed too greatly.

Welding Procedure

Distortion is affected by the welding current and voltage, the welding speed and the consequent rate of heat input, and by the rate of cooling. Weaving of the electrode has been reported to reduce distortion. Research, as well as experience, has shown that relatively high rate of heat input causes less distortion in weldments of appreciable size, and that it is usually better to use the least number of passes, for a weld of a given size, that can be used without involving such thick layers as to sacrifice soundness.

This indicates the use of high-melting-rate electrodes of comparatively large diameters, and high welding currents and speeds of welding, with work positioned for as much down-hand welding as possible. Heavier slag coverings over the weld keep it hot and plastic for a longer time so shrinkage can be absorbed, which is quite important.

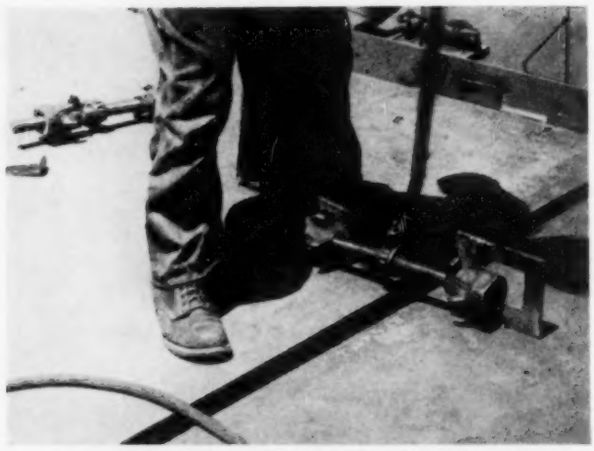


Fig. 9—Push-Pull Jack Is a Most Useful Tool for Fitting, Where a Large Force Must Be Exerted

There is still a lot of controversy over this subject, largely because the principles mentioned cannot be applied indiscriminately to all thicknesses of materials and types of weldments. There is a maximum diameter of electrode and rate of heat input that any given thickness of plating will withstand without developing local kinks because it, together with the structural system or temporary stiffeners that may be attached to it, do not have enough inherent stiffness to withstand the forces set up. Work that is clamped, dogged or weighted down, or restrained in a heavy jig will admit the use of higher heat input and faster welding than if free.

It would be a mistake to use $^{5}/_{16}$-in. diameter electrodes for welding stiffeners to 5- or 6-lb. plates. On the other hand, in welding the face plate to the web of a heavy girder, the use of $^{5}/_{16}$-in. electrodes would not cause local kinking and it would reduce the over-all bowing or twisting distortion as compared with making a greater number of passes with $^{3}/_{16}$-in. electrodes. Multiple passes create what has been termed by European researchers, a "régime chaud" (an extensively heated region), which leads to distortion, because the widely heated region goes on shrinking both transversely and longitudinally, after the metal near the weld has cooled below the hot forgeable stage, and while colder regions further away do not shrink much. This difference in amounts of shrinkage causes buckling in the parts that shrink less.

For a further discussion of physical properties of steel at various elevated temperatures and their effect upon residual stresses and distortion, the reader is referred to pages 1085 and 1086 of the 1942 *A.W.S. Handbook*.

Twin arc welding, from both sides of a joint at the same time, and deep penetration into corners at T-joints, have been found to reduce distortion, even though the total amount of heat input is increased, as when the external fillet portions are built up to nominal size. The greater rate of heat input and the balance of heat, account for the reduction in distortion, especially angular distortion such as cupping of face plates or that occurring in plates at fillet welded stiffeners. In using twin arcs, one of them is usually made to lead the other one by about 3 in.

A complete written standard welding procedure should be drawn up for all sizes of welds, including size of electrode, welding speed, number and location of passes, etc. Welding current usually is difficult to determine directly, but welding speed together with size of pass afford a control over current. A common occurrence, leading to distortion, which results from lack of a standard welding procedure is the piling up of excess convexity or "reinforcement" of butt welds. When irregular fit-up or joint preparation makes it impossible to follow the standard procedure, it is better to change to a smaller electrode for the last pass than to pile up excess metal.

More research into welding procedure is needed to settle some controversial questions and to explain apparently erratic behavior at times. An example of such behavior is the simple case of welding on the hatch girder illustrated in Fig. 11. Once the web and face plate have been tack welded together securely they act as a composite section to resist bending or bowing due to weld shrinkage, with neutral axes, *x-x* and *y-y*, located as shown. Designers are always advised to balance welding as well as possible about these axes, to provide for balanced heat and balanced shrinkage.

When the welds *a* and *b* are made and have cooled and shrunk, the girder bows laterally as indicated, which is surely to be expected. The deeper, stiffer web prevents much bowing vertically. If a second pass is added to each of welds *a* and *b*, the lateral bowing or distortion is increased. If, however, a chafing bar is next attached by welds *c* and *d*, on the same side of the neutral axis *y-y*, instead of increasing the lateral bowing, this reduces it, perhaps to half the amount created by welds *a* and *b*, despite the fact that *a* and *b* now join the web to the face plate very substantially and continuously.

This behavior suggests that just enough heat from welds *c* and *d* may have penetrated through the thickness of the face plate to relieve a large part of the residual longitudinal shrinkage stress in welds *a* and *b* and the adjacent base metal. It is not entirely clear just why subsequent passes in multiple pass fillet welds act in the opposite manner.

Welding Sequence

Foreign technicians appropriately differentiate between "welding paths" or patterns (referring to the order and direction of depositing increments within a weld), and welding sequence (referring to the order of executing various welded joints or the layers and passes of these joints).

The virtue of using step-back, skip and wandering welding patterns has been discussed under Restraint and Plastic Yielding. Step-back and skip welding seem to operate in the same manner by breaking up the continuity of the shrinkage and thereby reducing distortion. Skip welding also disperses the heat of welding more widely and is therefore more effective. It has been criticized as setting up higher local residual stresses, but there seem to be no records of any adverse results from such highly localized stresses. In hot weather, wider skipping between deposited increments and skipping over a wider area may be necessary to prevent building up too much heat locally in one part of an assembly.

Skip welding is used effectively for intermittent as well as continuous welds. In the case of continuous welds, each deposited increment is the amount naturally laid down by one electrode, or perhaps one-half electrode for very light material. The distance between successively deposited increments varies from say two to four feet depending upon thickness of plating and upon temperature. Scattering out a number of operators uniformly over an assembly helps to avoid distortion from localized heat.

In welding stiffeners or beams to plating, the wide dispersion of heat seems to be most important. Some fabricators weld from the center outward, others from the plate edges inward, after having first tack welded the

stiffeners securely to the plating. In some yards, even on small assemblies that have been heavily tack welded, the welding is started at the center and carefully arranged to proceed gradually outward in all directions toward free edges. In other yards the practice is to make first all welds, butt and fillet, running in one direction, thus to first shrink the assembly most in one direction (transverse shrinkage being greater than longitudinal). Then all welds running perpendicular to the first welds are made, shrinking the assembly mainly in the other direction. The welds made first are those that will add up to cause the greatest amount of transverse shrinkage.

If wandering or skip welding is used in connection with each of the above described sequences, and if the assembly is not unusually large, there seems to be little difference in the effectiveness of these various methods, especially after the first series of increments has been laid down. Prior to that, if special fitting devices are used in lieu of tack welds and relative slipping is permitted, the sequence from the center outward likely has some virtue.

The direction of travel makes a great deal of difference in the case of welding continuously along a butt joint, especially if the joint is not heavily tack welded in advance. Use can be made of the tendency for such a joint to close up as welding progresses, in controlling the camber in a beam or girder with vertical splices in it.

Some shipyards erect vessels in three or more separate sections, one at the bow, one at the stern and one or more amidships, leaving girth butts between these sections to be made last. Here again the direction of welding these girth butts can be used to control the longitudinal camber of the ship and any tendency for part of the hull to rise off the keel blocks.

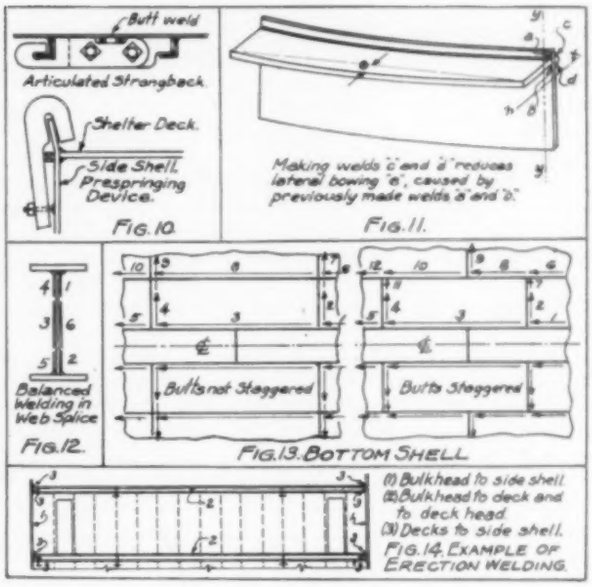
In very large subassemblies and in erection welding, nearly all shipyards follow a general sequence of welding starting at the center and progressing forward and aft and outboard. If tack welds are made much in advance of the welding, they can be made light enough to break under cumulative shrinkage stresses, or in lieu of tack welds, devices can be used which permit slipping. Such a "stress-free" general sequence does not prevent the use of skip welding over limited areas.

Most yards are quite careful to follow a predetermined sequence for welding side shell plating, starting at the midship section and welding forward and aft on each successive strake from the bottom upward, catching the butts in the next strake above as they are encountered while welding on each longitudinal seam. By the time welding in the midship section has reached the sheer strake, the lower strakes have been welded clear to the bow and stern, and intermediate strakes about proportionately.

At this point practice differs for the remainder of the shell plate welding. Some yards continue on in the same manner, completing the welding of the sheer strake last. Others proceed from the point mentioned, by jumping up to the sheer strake and completing it next, and then completing each successive strake below, finally ending near the fore and after peaks. Some minor departures from these schemes are necessary occasionally to prevent lifting off the keel blocks.

Bottom shell welding invariably starts at the keel amidships and is carried forward and aft and outboard. Butts are welded in the next adjacent outboard strake as welding progresses along each longitudinal seam; or possibly a number of the butts are welded ahead in a strake before it is welded along its inboard seam.

A minor deviation used to prevent "sinking" at corners where butts and seams intersect, is to stop the welding of each butt about 6 or 8 in. short of its intersection


Butt weld
Articulated Strongback
Shelter Deck
Side Shell
Prespringing Device
Making welds c and d reduces lateral bowing e, caused by previously made welds a and b
Balanced Welding in Web Splice
Butts not Staggered
Butts Staggered
(1) Bulkhead to side shell
(2) Bulkhead to deck and to deck head
(3) Decks to side shell
FIG. 10. FIG. 11. FIG. 12. FIG. 13. BOTTOM SHELL. FIG. 14. EXAMPLE OF ERECTION WELDING.

Figs. 10–14

with the outboard edge of the strake; and then when the welding of the seam along the outboard edge of the strake has reached this intersection or corner, the unwelded 6 or 8 in. is completed. When butts are not staggered, the welding is simply continued right on outboard across the intersection and into the next strake (Fig. 13). This same general scheme can be applied to welding the side shell, also.

Some shipyards let the erection advance far enough ahead of the welding so that a carefully worked out sequence can be followed for all erection welding, the general scheme of progression being based upon principles of stress-free welding.

Since decks are usually stiffer and more rigid than 'tween deck bulkheads, it appears that they should be fully welded above and below any bulkhead before the boundary welds of the bulkhead are made. Specific examples have been noticed of fair bulkheads being warped quite badly by welding on the deck above.

On light vessels, particularly, a good deal of difficulty is experienced if a suitable sequence of erection welding is not followed. Bulkheads which are fair when erected may become badly buckled throughout. Transverse deck beams may twist and snake out of line between longitudinals. In Fig. 14 is illustrated a typical example of a sequence that has been found satisfactory in practice.

Design

Although design is often blamed for more than its share of distortion troubles, there is much that the designer can do to facilitate distortion control. Some matters of design have already been discussed under previous headings.

One of the most important things is to hold down the size and amount of welding to the minimum required for strength, elastic stability and balanced design. This cannot be realized by basing weld sizes and lengths solely upon scantlings.

Of course, suitable limits for maximum spacing of weld increments in various kinds of primary and secondary members must be prescribed to prevent local crippling and to provide for adequate stress distribution, just

as corresponding limits are prescribed in all structural design specifications for riveted work. Minimum weld sizes for various ranges of thickness of material have now become standardized in specifications for bridges and buildings, just as minimum rivet sizes are specified, but these sizes are in no way predicated upon the strength of the section.

Provisions of structural and bridge specifications relating to elastic stability, which have been developed from experiments and through experience, conform quite closely to theory as developed by Moisseiff and Lienhard in their "Theory of Elastic Stability Applied to Structural Design," *Transactions of the American Society of Civil Engineers*, **106,** 1052 (1941).

In most cases minimum weld sizes govern so that continuous welding results in more deposited metal than the minimum permissible amount of intermittent fillet welding for a given application, and therefore continuous welds cause more distortion. For example, intermittently welded inner bottom assemblies are of heavy enough material that they can usually be welded without distortion, even though very meager preventative measures are taken, other than adequate tack welding. In some yards that still use continuous welding throughout these assemblies, skip joints have to be left at about every fifth floor to relieve cumulative shrinkage, and these joints are welded later. In addition to this precaution, tank top plating must be dogged down and sometimes presprung into a reverse camber to compensate for warping.

In some cases where elastic stability rather than strength is the controlling consideration, matched or chain fillet welds can be changed to staggered welds, omitting each alternate opposite increment and thereby cutting the welding in half.

A structural arrangement that affords stiffening in two directions, involving both longitudinals and transverses, resists welding distortion much better than framing or stiffening in only one direction. It also provides better resistance to axial forces in the plane of the plating of decks and bulkheads, which is often as important a criterion of design as resistance to normal loads.

Various proposals have been made by naval architects and shipbuilders to eliminate buckling. For non-structural bulkheads, these include the universal use of free standing marinite bulkheads, especially where marinite sheathing is required anyway; or the use of free standing, lightweight, deformed metal bulkheads with panting clips or with boundary connections that are just tack welded lightly to prevent rattling.

It has also been proposed to replace some structural bulkheads which are not required for resistance to racking, with non-structural bulkheads and a supporting system of beams and stanchions.

Plating which has been corrugated, crimped or otherwise deformed to some regular pattern, offers another expedient to provide general stiffness and to break up flat surfaces so small amounts of distortion will not be noticeable. This scheme has been applied extensively to the production of truck bodies, busses and lightweight railway rolling stock.

Certain details used for bulkhead stiffeners are not well chosen; for example, angles or flanged plates with both toes welded to the plating and the heel outstanding, and even flat bars and small, solid, half-rounds, welded flat against the plating. These details are almost worthless as stiffeners to resist either loads or welding distortion because of their small moment of inertia.

The designer can also facilitate distortion control by arranging details as well as possible to balance the heat and distorting effect of the welding, and by following other well-established principles of good welded design.

A mistake commonly made in welded design is to assume that beams with fully welded end connections are fixed and develop an end moment of $wl^2/12$, whereas, more often than not, they are end connected to supports that deflect, and sometimes very little end moment is developed. This means there is a great deal of excess welding and often some excess structural material that cannot possibly function to any advantage because of lack of continuity.

It is well known that both axial and bending loads on unsymmetrical sections such as angles, flanged plate beams and channels, cause lateral deflection because of unsymmetrical internal forces. Such sections are much less efficient structurally than symmetrical sections such as tees and beams. Also, the tendency toward lateral deflection or bowing causes angular rotation or twisting which surely must contribute somewhat to buckling in plating to which such sections are welded (Figs. 3*a* and 3*b*). Symmetrical sections are recommended wherever their use is at all practical. Steel mills should be prevailed upon to roll more sections adapted to welded design.

Stiffeners or beams can sometimes be used in lieu of doublers to reinforce decks under winches and other concentrated loads, with a reduction in welding and its accompanying distortion, as well as a saving in steel material. Where a severe condition of surrounding restraint exists, as in heavy decks or flat of side of a ship, cracks have occurred sometimes, when heavier, welded insert plates have been used, in lieu of fitting doublers, where reinforcement is required to compensate for cutting openings. When doublers are used, no trouble of this kind seems to be experienced.

Where strakes of deck plating are laid transversely and their ends are butt welded to a heavier longitudinal stringer strake that lies along the side of the ship, the outboard edge of the stringer strake distorts badly during subassembly welding. Then when this edge is lined and fit to the side shell during erection, this throws buckles into the transverse strakes. The longitudinal shrinkage of welding to shell and to hatch side girders throws more buckling into the deck.

This is a typical example of a need for more design study. An easier design to execute would be to run the transverse strakes out to the side shell and provide a longitudinal stiffener under the deck about 3 ft. inboard from the shell. This could be made to provide the same longitudinal axial resistance as well as the same transverse bending resistance as the heavier stringer strake. Or, if an extensive redesign is possible, a change to a longitudinal framing system, for the decks, which seems desirable for other reasons, would make it especially convenient for all strakes of deck plating to be run longitudinally, which would reduce the distortion a great deal.

It is nearly always advisable to use the widest plates obtainable, for bulkheads as well as decks. The reduction of welding thus accomplished saves time and saves more cost than the extra charge for the wider plates. With a 96-in. maximum obtainable width, which prevails under war conditions, it is necessary to run superstructure bulkhead and house-side plating vertically, with frequent seams, or else to use a coaming plate to make up the required height. The extra welding involved makes distortion control more difficult.

At doorways, distortion can often be reduced and some steel saved also, by fabricating the bulkhead in two pieces, one on each side of the door, and using a lap-welded head piece to fill in over the doorway, rather than making a door cut out of solid plating.

It is sometimes possible to shift the location of a

welded joint to a place where it will cause less distortion or where distortion can be controlled more easily. It is easier to strong back butt welds effectively in bulkhead plating when they are not located too close to stiffeners that run parallel to the welds. It is desirable to prevent the concentration of shrinkage which occurs when several welds are near to each other.

It is only logical that there should be many opportunities for improvement in the design of welded ships, in view of the comparatively recent changeover from riveted construction. The designer must keep in touch continually with production to make sure that his details are such as to facilitate practical construction operations.

(*Part II of this article, which will appear in a subsequent issue, relates to methods of correcting distortion, including oxyacetylene flame straightening.*)

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(*Continued on page 694*)

Welding—Its Application to Aircraft*

By Francis H. Stevenson†

IN the Aircraft Industry today there are two main welding processes in use. These are resistance and fusion.

The fusion process is divided into two types, gas and arc. Let us look into the gas welding first. This includes oxyacetylene and oxyhydrogen, the hydrogen being mainly used in the welding of aluminum parts, such as oil tanks. The oxyacetylene process is used on all small fittings, such as pulley brackets, etc. There are a number of points to be watched, namely, thorough fusion between the base metal and the metal added from the filler rod is necessary throughout the entire weld. Theoretically it is indicated that a strictly neutral flame be used when welding S.A.E. X4130 with the oxyacetylene process. However, we have found that by using a very slight feather on the flame that much better results are obtained. This slight excess of acetylene has a fluxing action on the surface oxides, yet does not cause carbon pick-up by the base metal. Another point to watch is the direction of welding. For instance, starting to weld at the edge of a piece will, nine times out of ten, cause a crack. Therefore, it is necessary that welds be made toward the edge by starting at some point in from the edge. Fit-up of the parts must be watched very closely. Some advantages of the oxyacetylene process are:

1. Low initial cost of equipment.
2. Can be used in welding a large variety of materials.
3. Can produce welds at reasonable cost.

The disadvantages of the oxyacetylene process are:

1. Excessive amount of expansion and contraction which must be taken into consideration.
2. It requires highly skilled operators to produce a good weld.
3. It is not satisfactory for heavy sections.

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† Asst. Superintendent, Vega Plant No. 2, Vega Aircraft Corporation.

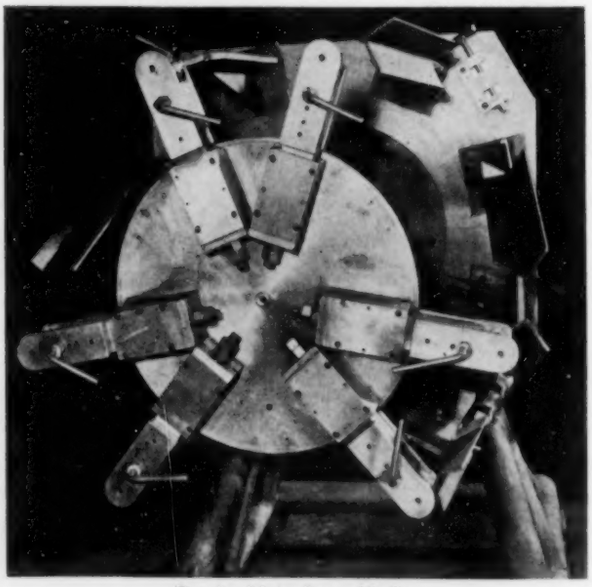

Fig. 1—Main Assembly Jig

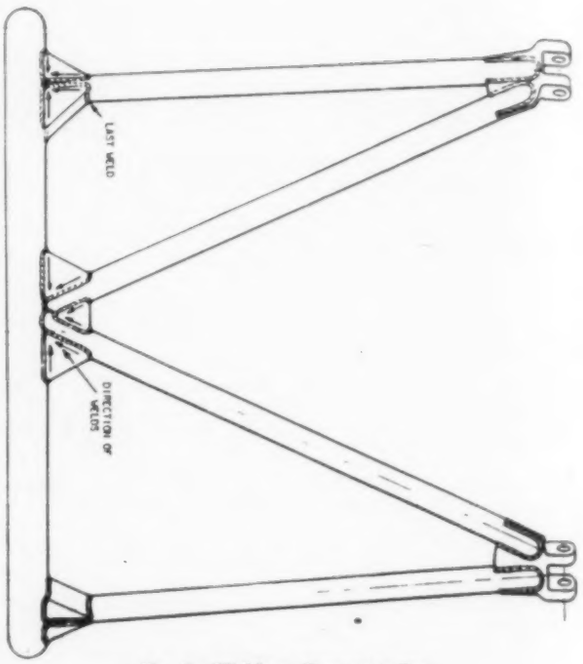

Fig. 2—Welding Gussets to Ring

Now let us look at the arc-welding process. This process has made great strides in the last few years in the Aircraft Industry and the manufacturers on the West Coast seem to have pioneered this process to a great extent. Some of the advantages of this process are:

1. Its ability to produce strong, sound and ductile welds.
2. It can be used to weld nearly all varieties of carbon and alloy steels.
3. It is adaptable to automatic welding.
4. It can produce satisfactory welds in heavy sections as well as light sections.

Some of the disadvantages are:

1. The initial cost of welding equipment is relatively high.
2. It requires highly skilled operators to produce good welds.

At this point let us go into the shop and watch a motor mount being welded in the main assembly jig. This will give you an idea of the procedure used. This main assembly jig is shown in Fig. 1.

You will notice the clean lines and accessibility of the jig; these points will be discussed later. Of course, there will be different procedures used for different structures but this will illustrate some of the main points. After the parts are all located in this jig a preheat is given the part to be welded, this being 250 to 350° F.

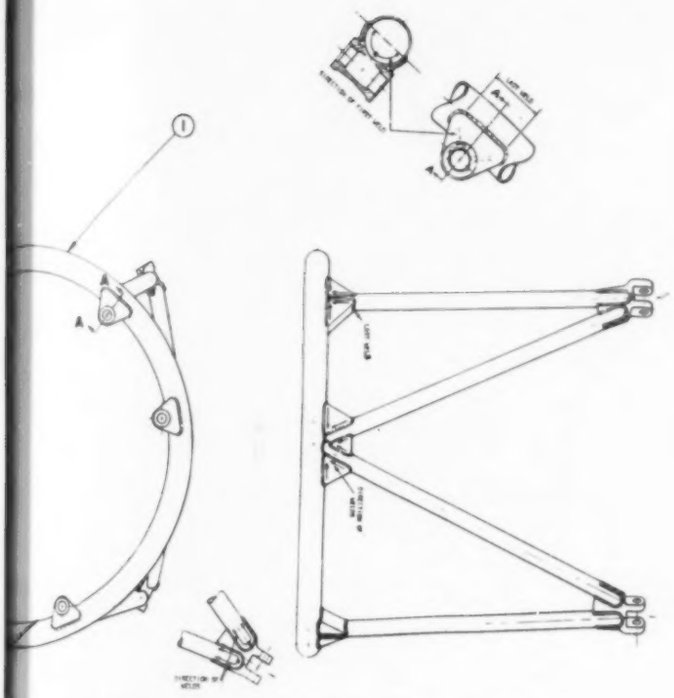

Fig. 3—Welding Feet and Motor Forging Into the Ring

These welds are split and when one tube is finished the one opposite it is then welded. After all the welding is done that is possible in the jig, the mount is then taken out and the welding finished. Some trouble might occur at this point in the nature of cracks. However, most of this can be eliminated by correct fit-up. Our next step is to fit in the gussets. This is done by the metal fitter. After all gussets are fitted, they are held in place by a small clamp. The mount is then bolted by the feet onto a frame which is suspended between two trunnions and can be rotated in any direction. This enables the welder to sit on a stool and weld in the down-hand position at all times. The electrode used is mild steel coated and is $^{3}/_{32}$ in. in diameter. The current used will be 20 to 25 v. across the arc and 100 to 120 amp. Here, as in previous operations, a preheat is used, the temperature being the same as heretofore mentioned. The welding procedure must be watched very carefully, with all the gussets being welded to the ring first.

After one group of gussets is welded to the ring, then the next group which is directly opposite, is welded, and this procedure is followed until all gussets are welded to the ring. Our next step is to weld the gussets to the legs. The same procedure is used as mentioned for welding of gussets to the ring, with the addition of the last weld in each group of gussets being made on the back, as shown in Fig. 2.

The mount is then put back in the main assembly jig for cowling clips to be welded on if used, and a stress relief given. This is done to set the mount to the jig so it will be as nearly perfect as possible for the following machine operation. The temperature used for the relief operation is usually 500 to 600° F. The mount is then left in the jig to cool, then taken out and checked for trueness.

Figure 3 also shows direction of welds when welding feet and motor forging into the ring. It is noted that in the above, a preheat and postheat are used. This is always done with a hydrogen flame. Both in oxyacetylene welding and arc welding, hydrogen can be used to very good advantage for preheating, elimination of scale and in helping control expansion and contraction of very thin sections. While it actually heats, of course, it seems to have the property of cooling or at least of spreading the heat from the weld so that distortion is not so apt to occur. The simple hydrogen burner can be made of copper tube, and this can be made in various shapes or sizes as needed to fit the work. From the above, you will see how necessary it is to keep a good control over the welding procedure.

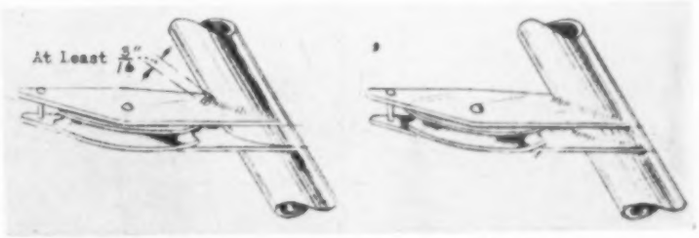

Fig. 5—Correct and Incorrect Welding of Single Pulley Bracket

Let us now look at some of the designs on welded parts —in this, the author will try to show some good and

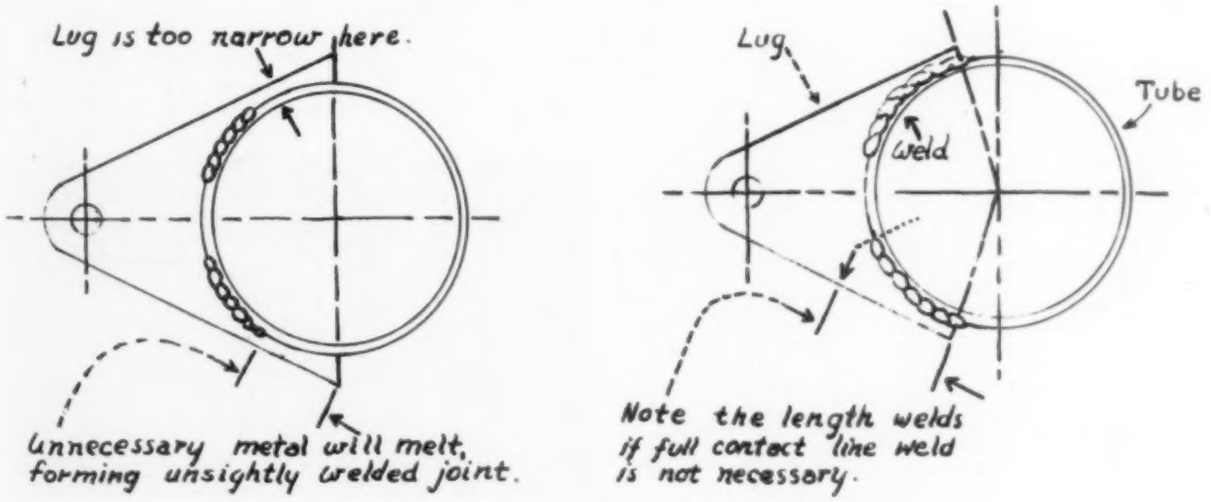
Lug is too narrow here.
Unnecessary metal will melt, forming unsightly welded joint.
Lug
Tube
Weld
Note the length welds if full contact line weld is not necessary.

Fig. 4—Illustrating Correct and Incorrect Design

bad designs as they affect the shop and ease of welding. It is thought that all too often engineers have little fundamental knowledge of welding, and assume that any two pieces of metal, regardless of their shape, size or position, may be joined by this process. In this connection, the author firmly believes that the shop should be consulted on new designs that call for welding.

The following are a few points that should be avoided when designing for fusion welding.

1. A joint between very thin and heavy material, because the heat required to bring the heavier metal up to the welding temperature may burn or melt away the thin metal. This is illustrated by Fig. 4. The end of the lug is thin and the welder is asked to make a neat job. This is impossible because the metal will melt away.

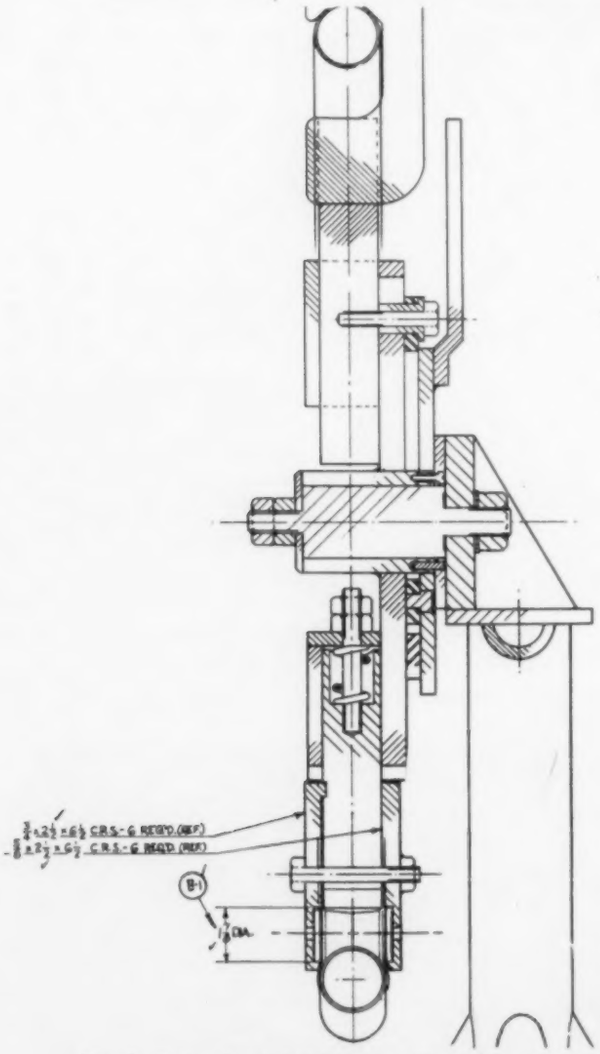

Fig. 6—Spring Loaded Holder on a Welding Jig

The design on the left shows how to overcome this so the welder will be able to do a good job.

2. Convergence of more than six members to form a welded cluster. The repeated application of heat on the small area where all the members meet weakens the base metal adjacent to the remelted weld metal.
3. A joint which requires welding at the inside junction of two members forming an acute angle, or welding in other inaccessible places.

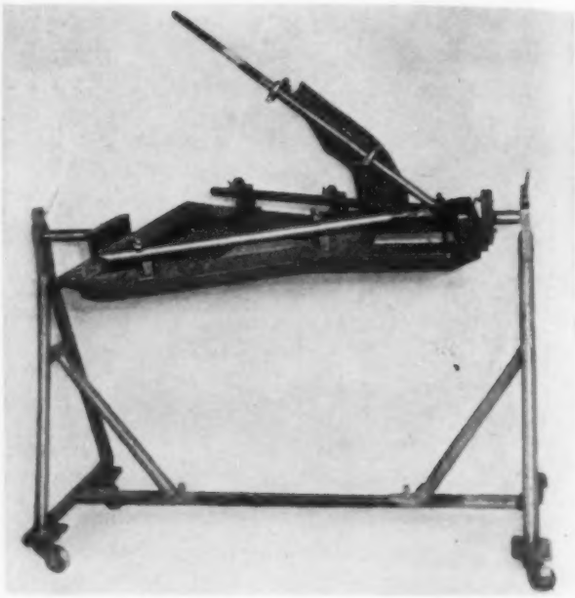

Fig. 7—Jig for Welding Mount Legs to the Feet

4. Complicated assemblies of many small parts. Simplify and combine parts.
5. Placing parallel weld beads close together. Either overlap the beads or keep a minimum of $^1/_4$ in. between nearest edges of beads. Figure 5 illustrates welding in confined places. The right-hand design being incorrect and the left-hand design being correct.

There are a number of other points that could be mentioned but on the whole, if the engineer will watch the above five points, we in the shop will be able to give him a better part both from the standpoint of the quality of the weld and the rate of production. Further, the engineer must realize that in the welding torch or the electrode he has a production tool that can be of great service to the industry in speeding up production.

The next point to look into is the question of jigs and fixtures to be used in holding the various parts that are to be welded. This is where the tool designers and the shop men always come to very heated arguments. However, it is absolutely necessary that the welding shop be consulted on all jigs and fixtures to be used by them; this will result in a jig or fixture that is usable.

Figure 6 shows a spring-loaded holder on a welding jig. This enables you to control expansion and contraction to a very fine degree, and is used quite extensively on the Vega welding jigs.

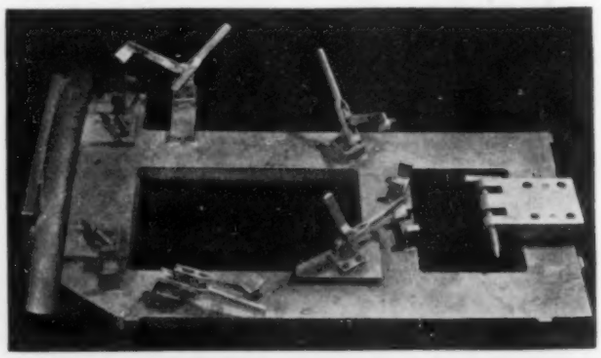

Fig. 8—Another Jig for Welding Mount Legs to the Feet

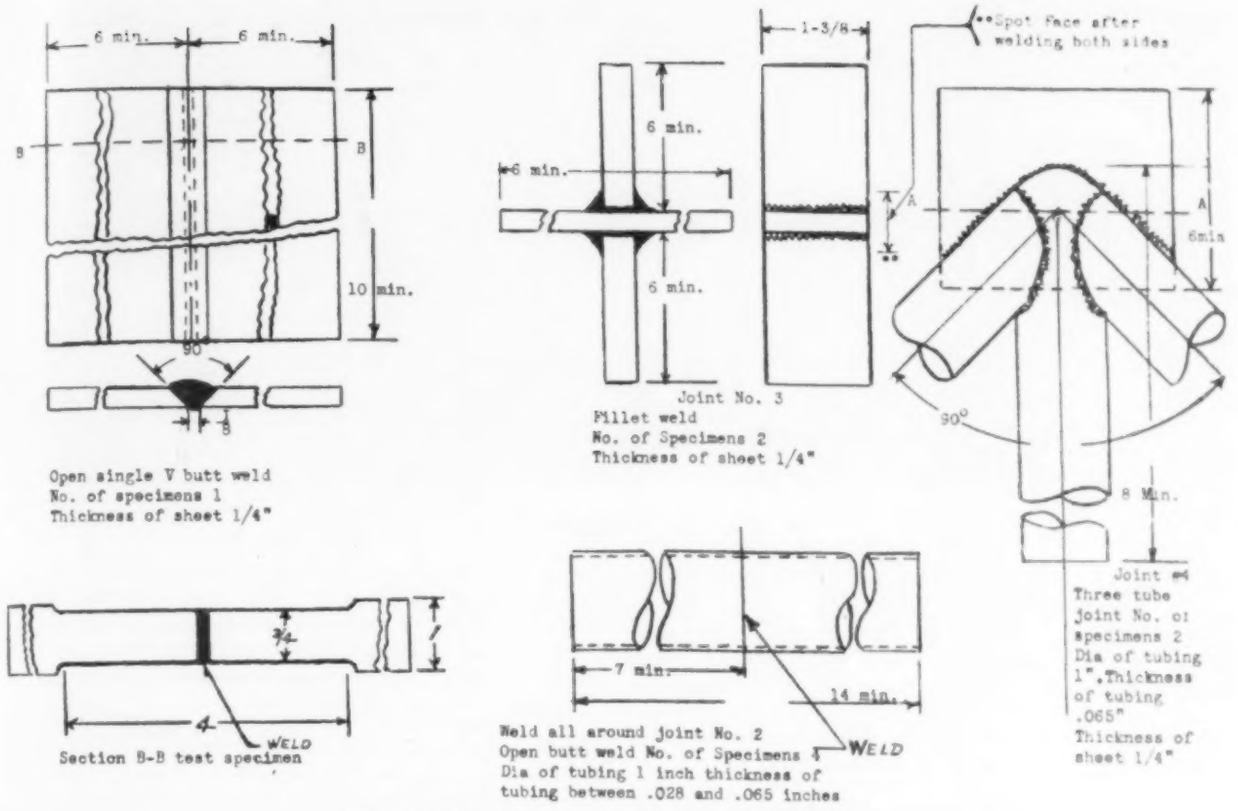

Fig. 9—Qualification Test for Aircraft Welders

Jig design for fusion welding of aircraft parts is not merely a matter of a few "C" clamps and pieces of angle iron but involves thorough consideration of the following eight points:

1. Proper allowance for shrinkage. Torch-welded parts shrink more than arc-welded parts. Stainless steel and aluminum have greater thermal expansion and contraction than low carbon steel.
2. Proper positioning. The work must be held in position to make a good weld, down-hand positioning is preferred.
3. Accessibility and visibility. The welder must not only be able to get at the work with the welding electrode or torch but must also be able to see clearly if he is to turn out high-quality production. The jig is shown in Fig. 7. This jig is used for the welding of motor mount legs to the feet. It can be rotated so that most of the welding is done in the down-hand position and also is very accessible.
4. Rigidity. The jig must be strong enough to support the part without excessive deflection, yet at the same time have sufficient flexibility to permit the normal shrinkage due to welding.
5. Heat control. The jig must carry away part of the welding heat to prevent excessive heat flow into the rest of the welded assembly.
6. Protection of work. On aluminum and stainless steel it is important not to mar the surface. Protective pads must be provided.
7. Convenience. Parts must go into the jig easily and the welded assembly must be easily and quickly removable.
8. Clamping devices. Screw clamps should be elimi-

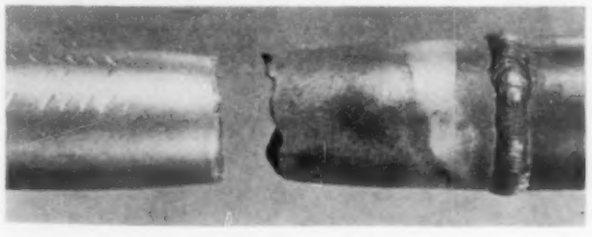

Fig. 10—Samples of Good Weld

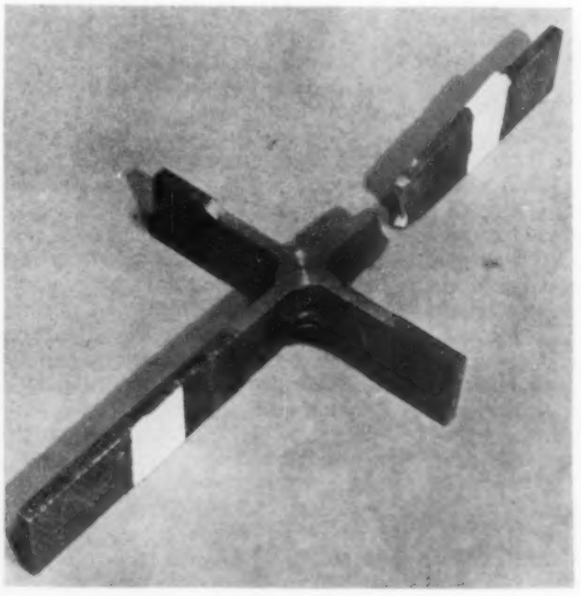

Fig. 11—A Good Example of the Cross Test

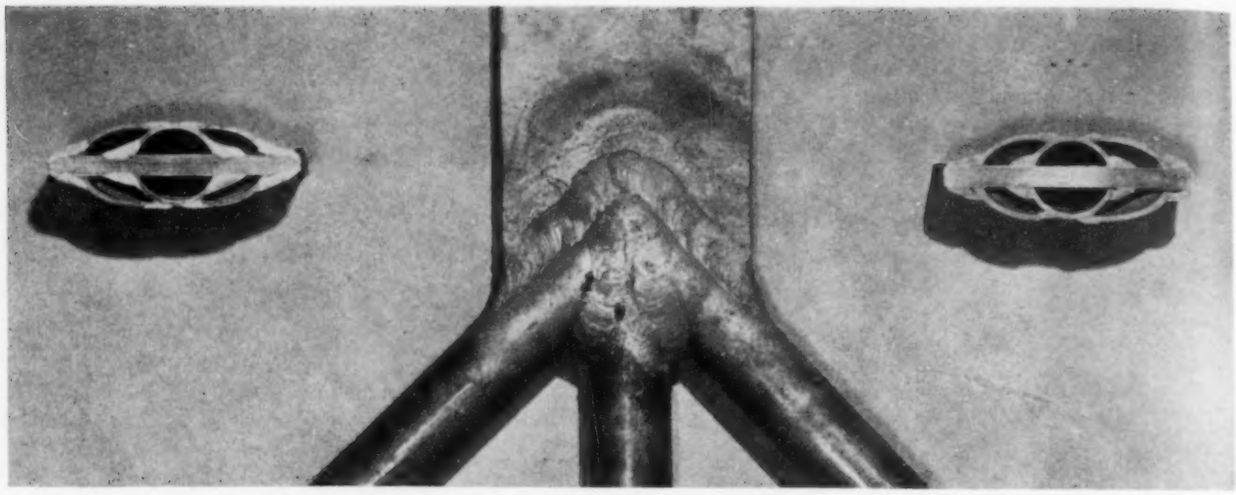

Fig. 12—A Cluster Weld

nated wherever possible, and quick-acting clamps used in their place.

The jig shown in Fig. 8 is also used for the same purpose as the one mentioned previously. However, you will note here that quick-acting clamps are used whereas the previous one had thumb screws. This jig is also mounted and can be rotated. At Vega, the shop men are always consulted on the design of a welding jig by the tool designers.

The question of tests comes to mind next. In the aircraft industry, any manufacturer who is building for the Army or Navy must have all his welders certified. This is done in accordance with Spec. 20013-B of the Army Air Force, or for the Navy Specification S.R.-14. These are almost identical; however, for this paper we will discuss the Army Specification. This, of course, applies to both arc and gas welding, and covers all the materials that are welded in the aircraft industry. We have five groups which are as follows:

Group I	Carbon steels
Group II	Stainless steels
Group III	Nickel steels
Group IV	Aluminum alloys
Group V	Magnesium alloys

In the carbon steel group there are four tests. These are: the plate, the tubes, the cross and the cluster.

This group is also divided into two classes, A and B. The A class being required to complete all four tests, and the B class being required to complete the first two only. The other four groups carry only an A class. The class A in Group I can weld any steel part on the airplane. A class B man can weld anything but primary and secondary structures. However, a welder carrying this certificate is not eligible to weld alloys in other groups unless he is certified in them also. (See Fig. 9.)

On Joint 1, which is the plate, two pieces, $^1/_4$ x 6 x 10 in. are welded together, and three standard tensile specimens are taken. These are then pulled in a tensile machine, with an alloy base metal and a filler rod of 0.06 carbon. The psi. must be 55,000 lb. The break is examined for good metal appearance.

On Joint 2, which is the tubes, there are four specimens: two are welded in the horizontal position and two in the vertical position with an alloy base metal and a filler rod of 0.06 carbon. The psi. must be 80,000 lb. Figure 10 shows a good sample. In this tube test note the elongation of the tube.

Joint 3, which is the cross, is welded in the vertical position and, with alloy base metal and filler rod of 0.06 carbon, must show a tensile pull of 15,000 lb. per linear inch. Break on this is examined for quality of metal. Figure 11 shows a good sample of the cross test. Note the elongation of base metal.

Joint 4, which is a cluster, is three tubes slotted and welded over a piece $^1/_4$ x 3 x 6 in. This is then cut and etched and examined for penetration. Figure 12 shows the cluster weld left-hand view showing very good penetration in both tubes and plate. The right-hand view shows poor penetration, and is, of course, cause to reject the welder.

For Groups II, III and IV, the test consists of two butt-welded joints in sheets of the chemical composition to be used in production work. One joint shall be made between two sheets of equal thickness, which represents the thinnest sheet to be welded in production. The other joint shall be made between sheets of equal thickness, but which represent the thickest sheet to be welded in production. The sheets usually are 6 in. square. These are

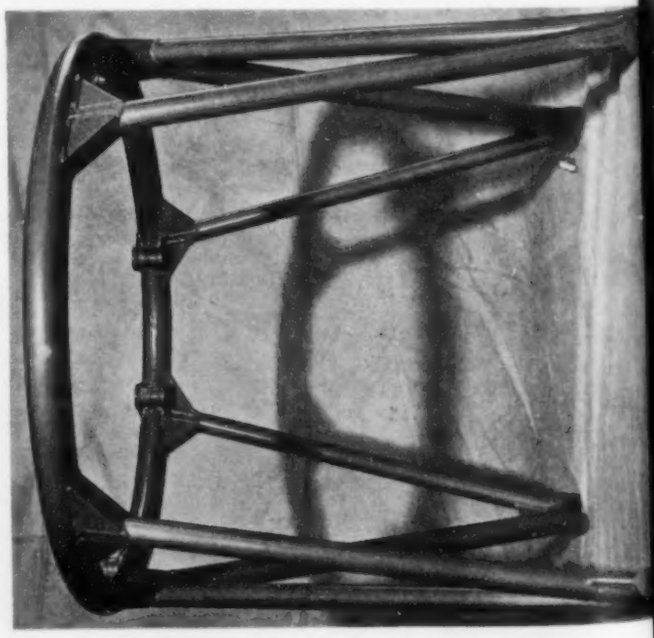

Fig. 13—A Mount Designed for Arc Welding

then cut into specimens approximately 1 in. in width. A specimen shall be bent 180° over one sheet thickness so that the outside of the bend will lie in the plane of the weld. The outside of the bend shall be on the side on which the weld is laid, for joints welded on only one side. The joint shall not crack or show indications of lack of bond between the welded metal and the base metal. The excess metal on either side of the sheet may be ground smooth with the base metal before making the bend.

The bend tests are not required for Group V alloys.

For a company to get the most of its welding shop, both in quality and production, it is most necessary to have a well-planned procedure control. Briefly, procedure control consists of the following:

1. Design for welding.
2. Selection and inspection of materials.
3. Establishment of a procedure which will give the results desired.
   - *A*. Preparation of material.
   - *B*. The welding procedure.
4. Qualification of the welding operator to follow the procedure.
5. Inspection and testing of completed work.

Design for Welding

A number of points have already been discussed. It is repeated here for emphasis and to show its relationship in the procedure control.

Figure 13 shows a motor mount which was designed entirely for arc welding. Note the clean lines of the finished assembly.

The Selection and Inspection of Materials

This includes base metal, welding rods or electrodes, gases and apparatus. The affidavits of reputable manufacturers are generally acceptable for the first three items: however, your apparatus, which includes gages, pipe lines and welding machines, should be inspected periodically.

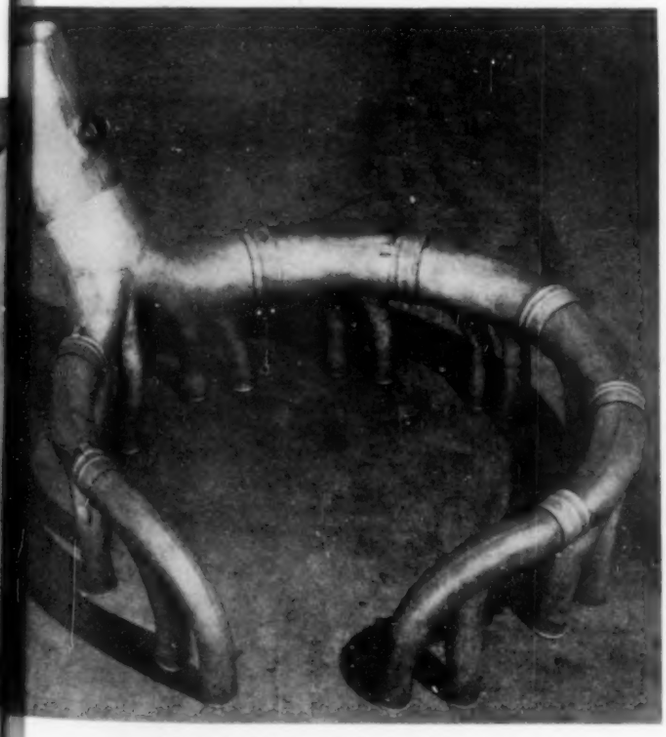

Fig. 14—Exhaust Collector Ring

Fig. 15—Flash-Welded Control Rod

Establishment of a Procedure Which Will Give the Results Desired

It is here that a great deal of thought and effort should be expended. In a great many shops, this is left up to the Head Welder. By doing this the shop may quite often get in bad because the part does not come out like the design, or does not do the work for which it was intended. It is suggested that all procedures be worked out in a research laboratory in conjunction with the Welding Foreman. This will give the engineer who designs the part and the man who makes the part an opportunity to get together and iron out the bumps. Also when the part is made in production, it will be able to perform the function for which it was designed. It is possible that the welding procedure could be marked on the blueprint, and the marking to indicate the starting and stopping points of all welds, the direction of welding and the welding technique. All operators are then required to follow that procedure exactly.

Figure 14 shows a complete exhaust collector ring. This was designed for the use of both oxyacetylene and arc welding. Also this ring can only be built in a welding shop where a welding procedure is strictly followed. This also applies to the aforementioned motor mount.

Qualifications of the Welding Operator to Follow the Procedure

This is a very important item inasmuch as shops not having procedure control will have scale welding, forehand welding, long and short arc and other pet techniques. The qualifying of operators is also helped by the use of Army and Navy specifications which were discussed earlier in the paper.

Inspection and Testing of Complete Work

The majority of welds inspected in aircraft is done by the magnaflux method. This is a requirement of the Army, that all welds be magnafluxed; however, the writer believes that the X-ray method is better for examining welds. If you take one out of every ten parts and X-ray it, you will get a high quality of work from your welding shop. You have a print which can be shown to the welder at any time and his weak points are recorded. Also, he never knows which part is going to be X-rayed, so he is on his toes at all times.

There are any number of welding jobs that could be put on a line production basis. This will increase the output with less skilled operators because it is easier to train operators to do one operation, for instance, the welding of gussets in a motor mount. There are a number of new

developments coming to the fore in the welding field. One of these that might be mentioned is flash welding.

There are some companies on the West Coast that at the present time are using flash welding in production. Some of the parts now being welded by this method are control rods and various small struts. Figure 15 shows a control rod which is now in production as a flash-welded article.

As to the future of welding in aircraft it is the opinion of the writer that we shall always have welders in the industry because the torch and the electrode are very good production tools, if used correctly. Some welders have said with all this resistance welding coming in, what are we going to do when the companies throw out fusion welding? There is going to remain a definite place for each process, and in our organization, we try to use the process which is the most practical, both from the standpoint of the ease with which it can be fabricated in the shop and the cost of the finished part. By doing this, we will be able to increase our production so that ultimate victory will be ours.

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Visual Inspection of Arc Welds*

By W. L. Warner†

MANY people perhaps do not realize the great extent to which welding is contributing toward the successful prosecution of our war effort. In many instances the advent of welding is entirely new. In others, welding has gained prominence because of conversion of existing industrial manufacturing facilities in which the welding process has, in the past, been utilized. Frequently one hears that this or that item of war production is months ahead of schedule. Those of us who have been associated with welding during the past decade or more know that welding, with its great improvements during the same period, is largely responsible. This is indeed a satisfying thought, and yet in the midst of the greatest national emergency ever existing, there must be a determination to further improve welding methods in order to make the most and best use of the materials available in the shortest possible time. The tendency toward excessive relaxation of quality standards which arises under the stress of war production must not be tolerated. There is no substitute for satisfactory quality. Satisfactory quality is not always easy to define. Where should be the dividing line between acceptance and rejection? This is the battleground of inspection.

The purchaser specifies certain requirements or characteristics for the article which he expects to obtain from the manufacturer. Sometimes these requirements are arbitrary but usually they conform to the best industrial practice. Various codes and specifications covering generally accepted standard procedures and requirements for welding have been adopted by the welding industry. Such codes and specifications are a benefit to the purchaser who has had no previous experience with the welding process because they act as safeguards and set up standard requirements for the finished product and prescribe approved methods of inspection by which compliance with these requirements may be determined.

These prescribed inspection methods provide for welding procedure and personnel qualification tests, as well as methods of inspecting the finished product before acceptance by the purchaser. It should be understood that the choice of welding procedure to be used and the qualifications of the personnel who are to use that procedure to produce the product desired by the purchaser, are the responsibility of the manufacturer, or "contractor." However, it is the right of the purchaser to ask assurance from the manufacturer that proper procedure and qualified personnel will be used, and to specify the basis for determining such assurance.

Since the manufacturer is responsible for the manufacturing procedure used, and all the details concerned with manufacture of the product, it cannot be expected that the purchaser or his representative, the inspector, has a right to tell the manufacturer how to make the product. Both the manufacturer and purchaser must recognize this responsibility and understand that the purchaser assumes no responsibility for the product until he has accepted it based upon the results of final inspection.

Visual inspection is one part—the essential fundamental part—of the inspection of the finished product. It is usually non-destructive but may, in some cases, involve certain destructive tests, such as trepanning. Magnetic and radiographic tests, also non-destructive, are used to supplement the visual inspection of the exterior of the welds in order to discover any evidence of discontinuities within the welds. For some types of weldments, such as certain classes of pressure vessels, radiographic examination is required of all welds. For structural weldments, radiographic inspection is used as a procedure-control tool for spot checking of the welds as a check on the uniformity of the welder's work.

It must be recognized that visual inspection shows the external appearance of the finished weld, but does not show the internal character of the welded joint, except that on single-pass fillet welds and butt welds, certain surface irregularities or discontinuities are indicative of improper arc manipulation, energy values or welding materials used. Proof of the existence of internal discontinuities in weld or base metal can be obtained nondestructively only by radiographic test methods. In the ultimate sense, the inspector can look inside the weld by radiography in addition to inspecting the outside visually. The use of this method should not only increase the effectiveness of the inspection operation, but also produce a deterring effect on the welder's possible tendency to slight his work.

Radiographic inspection is more costly than visual inspection because of the equipment, materials and handling required incident to its application. For this

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In this discussion, the ideas suggested are those of the author and are not to be considered as expressions of policy or procedure accepted by the Ordnance Department.

† Welding Engineer, Watertown Arsenal, Watertown, Mass.

reason the method is generally used for "spot checking" certain selected areas in the weldment which may be considered as representative of all the welds in the weldment. Also certain areas of a weldment may be specified to be radiographed because of the requirement that the welds in that area be of an especially high quality.

Arc welds are examined visually for size and amount of reinforcement, uniformity of the width and surface contour, and freedom from surface cavities, undercut, lack of fusion or overlapping, along the edges of the weld, and cracks in either weld metal or plate metal adjacent to the weld. Such inspection is often carried out with the aid of a low-power magnifying glass, aided by a small light of some sort, such as a flashlight, in order to help in identifying fine cracks and undercuts.

Visual inspection of welded structures may be very thorough and complete, or it may be quite cursory, depending upon the extent of the inspector's welding knowledge and his confidence in the welders and supervisory personnel of the manufacturing organization. The inspection burden is lightest and the result most satisfactory when the manufacturer's welding organization is competent, its welding procedure satisfactory and the work adequately supervised by experienced personnel.

It is desirable to visually inspect all of the welds on the structure and make a comparison of the appearance of those welds in inaccessible locations with those welds which are most readily accessible. Such comparisons will provide information as to the welder's ability and the amount of care he exercises to do an all-around good job. A knowledge of the character and ability of the welder acquired in this manner is most helpful in evaluating the significance of possible defects which may be found.

The inspector should be critical and observing in his visual inspection of the weld. He must to a certain extent be "hard boiled" and yet not waste time with inconsequential irregularities which may appear. The more experienced he is with the welding process, the better is his understanding of the significance of weld defects. He should create a reputation for fairness and sound judgment. It is not the inspector's responsibility to make allowances for conditions which may be considered sufficient to justify errors due to inexperience and mistakes in application of welding. The weld is either acceptable or rejectable in accordance with certain standards. There is no compromise.

In most cases, welds can be satisfactorily repaired by removing the defect and rewelding. There are certain requirements pertaining to the removal of the defect and rewelding which must be considered. These depend upon the type of defect, its location in the welded joint and the position in the weldment. It is essential that the defect be eliminated by the repair operation. The inspector's job does not end when he discovers and marks a defect for repair. He must also pass upon the acceptability of the repaired weld after determining that the repair has been satisfactorily made.

For example, in many cases a light or shallow undercut may be adequately repaired by running a single weld bead over the undercut, but on steels of high hardenability it is desirable either to preheat before running this repair bead or to run two beads, one over the undercut and the second over the junction between the first bead and the weld reinforcement. In the latter case, care should be exercised that the second bead does not touch the alloy base metal. If the undercut is narrow and deep, approximating a crack, it should be chipped or ground out and welded in a manner to accomplish the effect produced by one of the two methods indicated above.

Weld or plate cracks generally should be removed before repair by welding. However, on thin plate metal of $1/4$ in. thickness and less, plate cracks may, in some cases, be repaired by welding without removing the crack beforehand, but it is desirable that the effectiveness of such methods be proved in advance before allowing this method of repair. With steels of high hardenability, attempting to weld cracks without prior removal may cause them to increase in extent unless adequate preheating or a suitable bead technique is used. The only method which will insure the complete elimination of the crack is to remove it in some manner before welding.

A lack of fusion or metal overlapping at the edge of the weld should be removed before repair. Internal defects can be removed only by chipping, grinding or gouging them out. Excessively oversized welds are potential sources of hidden defects. A check test by radiographic methods will usually suffice. If no evidence of a defect is found, such welds should be accepted, but periodic check testing should be continued. Usually the oversized weld will eventually disappear, either because the welder does not meet his piece rate, or the manufacturer finds that his welding is running too high in cost. An equally important point is that the welds should not be undersize because they would then not adequately comply with design requirements.

Arguments are sometimes advanced that inspection should be waived to expedite production. The thought behind such arguments may be either that the product inspected is not of sufficient importance to justify the time and expense involved, or that the standards required are higher than necessary for the service required of the product. Then, too, the manufacturer may be worried about possible rejections. A competent and dependable welder recognizes the fact that to make a good weld requires the expenditure of no more time, energy or material than to make a bad one. It therefore follows that, if the welding process is utilized in a competent manner, adequate inspection of the welded joints produced by it cannot hamper production.

Inspection, if the procedure followed justifies the term, should be regarded as an insurance against errors or mistakes in the application of the welding method, use of improper materials or procedure and incompetent or careless workmanship. Adequate inspection is essential to any manufacturing procedure.

Sound weld metal deposited from commercial types of covered electrodes of low carbon steel will develop a yield strength of better than 50,000 pounds per square inch in a stress-relieved condition. When it is realized that this metal is in the "as-deposited" cast form, without the benefit of mechanical working, and normally has a carbon content of only 0.10% or 0.12%, then the comparison of these properties with those of rolled plate or steel castings of similar composition conveys an appreciation of the adequacy of such metal for joining metal parts together. The problem in welding is to apply this high strength weld metal to the metal of the parts to be joined in such a manner that its properties may be fully utilized in service. The object of visual inspection is to determine whether such joining has been properly done in so far as may be judged from the evidence obtainable. By such activity, together with adequate procedure-control methods, welding has been demonstrated to produce a most satisfactory and dependable product.

Cooperation between the manufacturer and the purchaser's inspector in the effort to satisfactorily apply welding will result in the ultimate success of the war production program.

Factors Affecting the Accuracy of Ordnance Machine Cutting*

By Howard G. Hughey† and August H. Yoch‡

PRESENT-DAY standards for flame cut shapes demand a much greater accuracy than was common a few years ago. To obtain this accuracy with the mechanically operated cutting torch, it is necessary to control many factors, among which is that of plate motion while the cut is being made. This condition can produce irregularities in the final dimension regardless of how much care has been taken to control the more obvious details of the setup. Because of the importance of this one item, observations have been made which disclose the nature and degree of the plate motion, the probable and actual effect upon the result and means of minimizing the effect.

A picture of the motion and its effect can be gained by considering the common portable type of machine. Where the track for the machine rests directly on the plate, any movement of the plate will shift the track in a manner which is dependent upon the relation of points of track support and the zone in which the motion occurs.

Where the machine is supported independently of the plate, the track will not be affected by any change of location of the plate, and the path traveled by the cutting tip will be defined entirely by the track location and action of the machine. The location of the cut on the plate then becomes a matter of relative location of the tip and plate at the point of cutting. The plate may move slightly, but the tip will not move correspondingly, thus creating an irregularity in the cut edge. With the various shape cutting machines, mounted independently of the work, we have this problem of relative location and its bearing upon accuracy.

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† Engineer, Apparatus Research and Development Dept., Air Reduction Sales Co.

‡ Machine Cutting Specialist, Applied Engineering Dept., Air Reduction Sales Co.

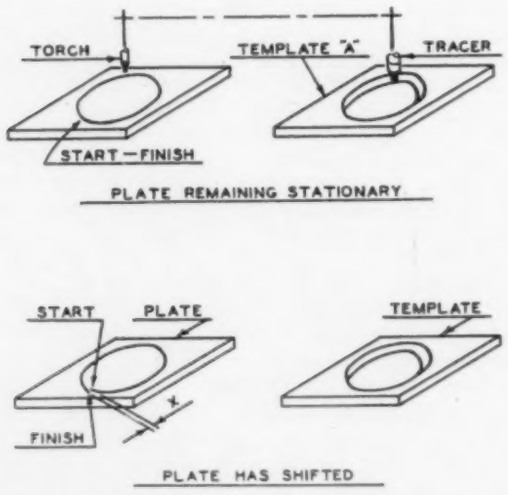

Fig. 1—Effect of Plate Motion When Cutting a Circle

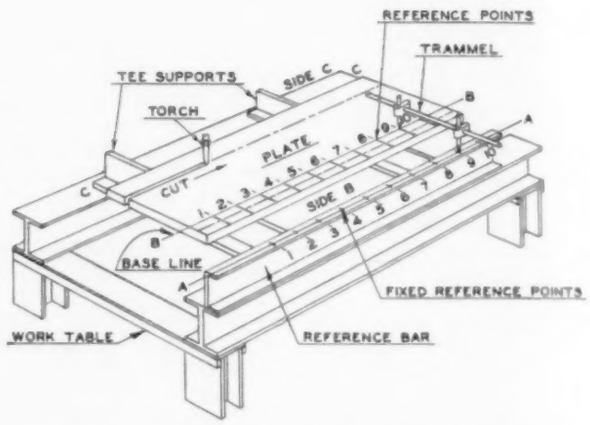

Fig. 2—Arrangement for Measuring Plate Motion

As an example, Fig. 1 shows conditions existing where the torch motion is controlled by a template, *A*, which causes the torch to describe a perfect circle, *B*. If the plate is perfectly stationary, the cut will be perfectly circular, *B*, but if the plate shifts while the cut is being made, the end will lie to one side of the start by an amount, *X*.

Plate Motion

Although the fact that plate motion exists has been recognized for a long time, only by making observations has the degree and manner of motion been determined. In forming some shapes, the movement of a portion of the plate is very evident whereas with other shapes, it may be so slight that it is not readily apparent, and an assumption might be made that no motion exists. Where accuracy is required, any definite information concerning this motion with respect to the point of cutting will provide a basis for predicting the degree of accuracy expected.

A series of observations have been made which provide some definite data on plate motion under different conditions. These observations were made on plates $1^1/_2$ in. thick and about $2^1/_2$ x 15-ft. face dimension. This size provided a satisfactory means for making sufficiently extended studies to obtain ample data, and the rectangular shape provided conditions which simplified taking measurements and making analyses.

The method of making observations involved means to permit making rapid and accurate measurements between the plate and reference points without interfering with the cutting operation. A general arrangement of the setup is shown in Fig. 2. A channel was secured to the table base, providing a reference section which would be unaffected by any action of the plate. On

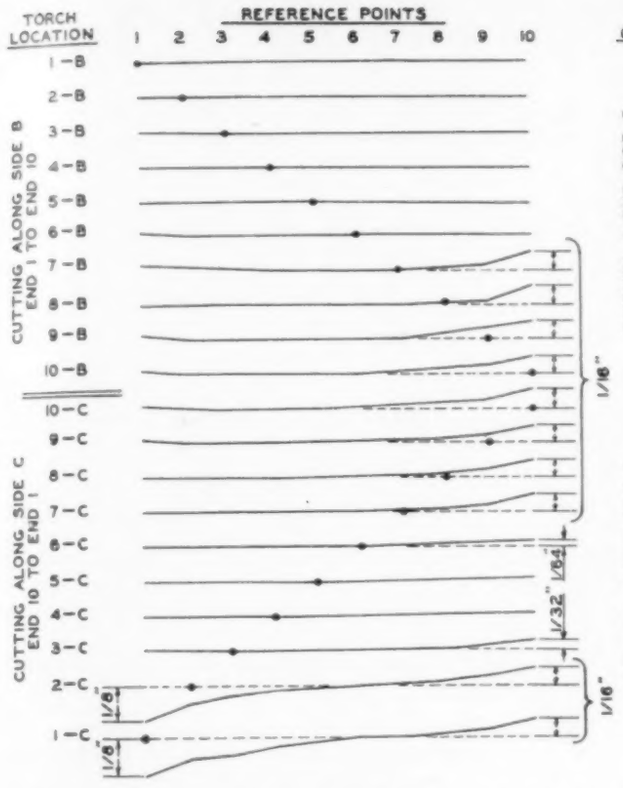

Fig. 3—Shifting of Base Line. Plate No. 4 Mounted on Mutilated Supports

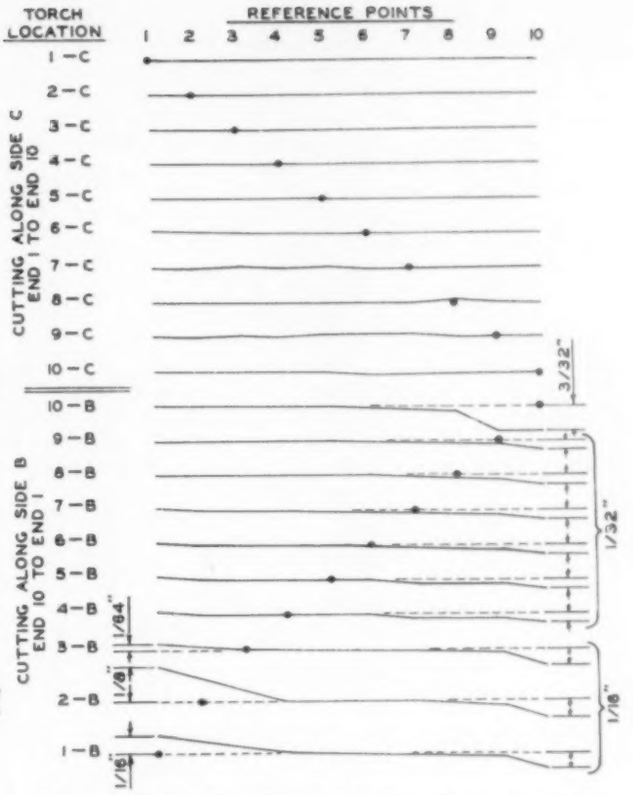

Fig. 4—Shifting of Base Line. Plate No. 3 Mounted on Mutilated Supports

the upper surface of this channel, a series of ten reference points were located. A trammel was used to locate points on the plate about 1 in. inside of the line of cut. As the cut proceeded along one side and back along the other, the dimensional change in the distance from reference point to plate point was recorded. Measurements were taken at all ten points each time the torch was at one of the points, making necessary 200 readings for a complete cut.

The first four plates were mounted on numerous tee irons which were badly mutilated from previous work and which presented a supporting surface of irregular points and slag deposits. The detail cutting conditions were set to provide a straight, smooth, high-quality cut and the scrap was removed as the cut progressed.

A graphical presentation of the accumulated data provided a picture of the motion taking place. The points on the plate determined a straight line before cutting, but as motion took place, this line developed a new shape which indicated the degree and direction of motion. Figures 3 and 4 cover the deflection of this line for two plates, and the heavy dots indicate the torch location or point of cutting.

In Fig. 3, it will be noted that for about the first 9 ft. no disturbance was apparent, but after this the uncut end began to move, shifting about $^1/_{16}$ in. and holding this position until the torch returned on the far side to a position about 6 ft. back. The plate then held steady again until about 2 ft. from the finish end. At this point it shifted angularly to the extent of $^1/_8$ in. on the finish end and $^1/_{16}$ in. on the opposite end, a total of $^3/_{16}$ in. motion.

A similar check of an additional plate with the cut starting on the far side and finishing on the near side is shown in Fig. 4. In this case no motion was in evidence during the cutting of the first side, but all during the cutting of the last side, a shift did occur, again to the extent of about $^1/_8$ in. for the last 2 ft.

Figure 5 shows the relative position on all four plates of this base line just before the torch completed its cut. The evidence here is that no definite pattern of motion existed.

After investigating this group of plates, a change in the method of support was made, using four tee irons so modified as to support the plate only in its mid-section in the area unaffected by the cutting operation. Six plates were then investigated. Figure 6 portrays the motion existing in one of these plates and is typical of all in the group. The existence of motion was restricted

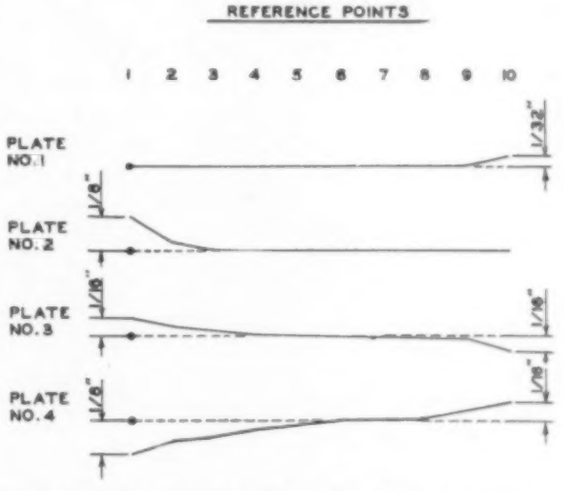

Fig. 5—Shift of Base Line When Torch Is About 6 In. from End of Cut. Plates on Mutilated Supports

to a 3-ft. section and the magnitude was only $^1/_{64}$ in. While the contrast of this motion to that of the first four plates is obvious, it was of particular interest to note that the pattern of motion for all six was markedly similar and that the maximum motion always occurred in the same region. Figure 7 shows the position of the base line on the six plates just prior to the finish of the cut and is to be compared to Fig. 5. Plate 10 was made with two torches making simultaneous parallel cuts and disclosed a motion of $^1/_{32}$ in. behind the point of cutting.

The significance of this motion lies in the fact that this, coupled with other factors can seriously affect the final results. Where motion exists ahead of the torch, the actual dimension is affected. Assuming that the plate motion is the only factor which affects the line of cut, these data in conjunction with the torch location and direction of travel can be used to predict the general finished shape and the general expected location of errors. In the case of exterior cuts, as for the plates discussed, any movement of the plate inwardly from the line of cut and just ahead of the torch will result in a plus dimension whereas any plate motion outwardly will

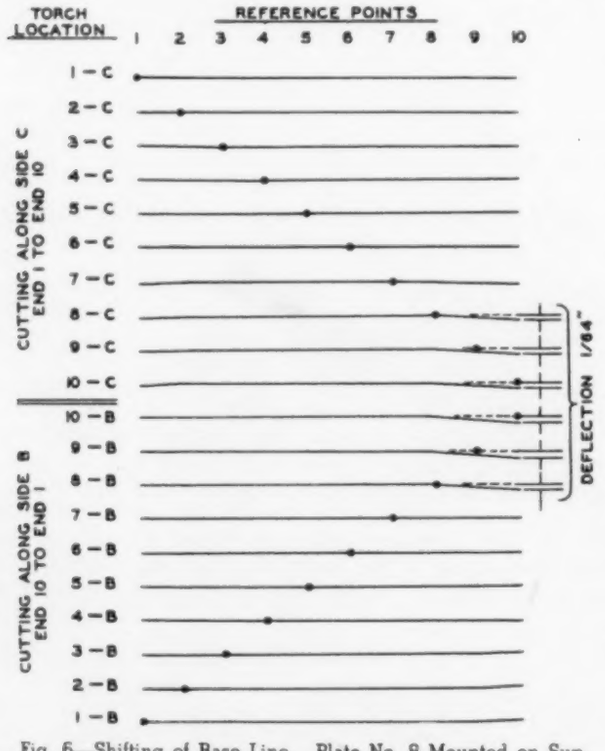

Fig. 6—Shifting of Base Line. Plate No. 8 Mounted on Supports Giving Free Motion

produce a minus dimension. Applying this analysis to the plates in question, a prediction of the probable errors was made and is shown on Fig. 8.

While the motion data can be used as a theoretical basis for analyzing the probable result, subsequent changes that occur during cooling may introduce changes in equilibrium that further alter the shape. In addition, variations may have resulted from conditions that affected the line of torch travel or from changes in operating setting. These variations would not be evident in the motion measurement and would be disclosed only by inspection of the final plate for straightness. Actually this means, after the plate has assumed its final form, how straight is the straight line that was cut?

To determine the final shape of the plates studied, a

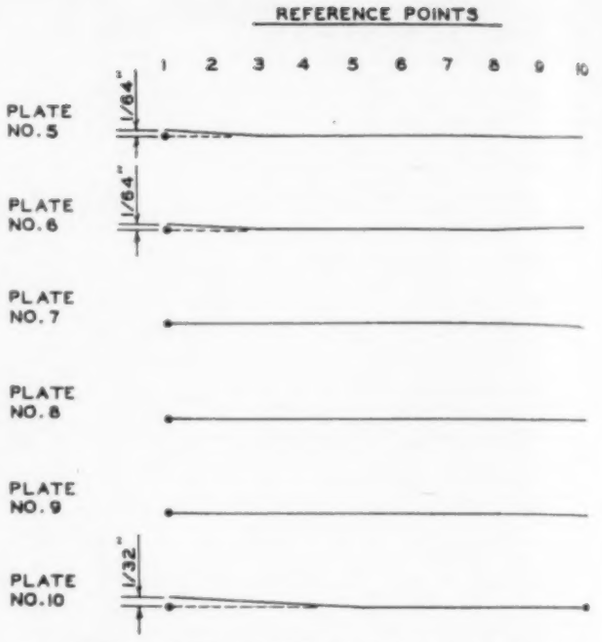

Fig. 7—Shift of Base Line When Torch Is About 6 In. from End of Cut. Plates on Supports Giving Free Motion

tightly drawn piano wire was used as a reference line in conjunction with suitable instruments, and measurements were taken to the edge of the plate. The results of such measurements on the three plates are shown in Fig. 9. The general predicted inaccuracies (Fig. 8) are evident, together with additional deviations.

As a matter of interest, the foregoing method of investigation was applied to a shape embodying both a rectangular portion and a section tapering down to about 6 in. wide. Two similar pieces were cut from a single plate, and this involved three distinct cuts. The first cut, which produced a large rectangle about 3 x 16 ft., disclosed motion to the rear of the torch similar to that shown with Fig. 5. However, the second cut, which severed the piece along the tapering line, caused motion to take place to the extent of $^1/_2$ in. This occurred at the small end of the tapered section and to the rear of the torch. Subsequent checking for straightness after cooling disclosed a final deviation of only $^1/_{16}$ in.

The analysis of the motion brings out the fact that the cut may be affected by either of two resultant conditions. The first is the "snaking" of the plate in itself.

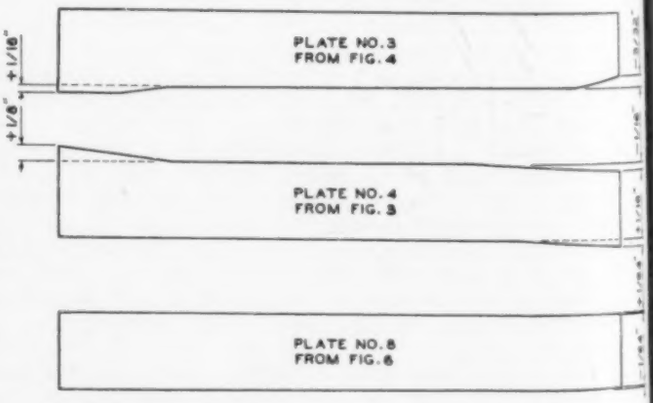

Fig. 8—Expected Inaccuracies from Shift of Plate While Cutting

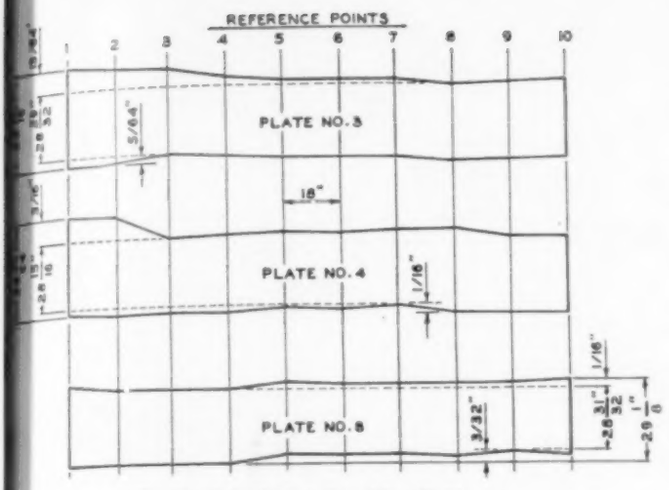

Fig. 9—Actual Deviation After Cutting

The second is the bodily movement of the plate when one side rests against a rigid point, thereby providing a fulcrum point. If the plate tends to move and is stopped by some projection or excessive friction, a rotative effect may result. In the case of the group of four plates, Figs. 3, 4 and 5, a condition of this nature must have existed since they followed no repetitive motion pattern, and no control of the motion was evident. The second group of six plates apparently had no rotative tendency, the type of support permitting sliding to accommodate the "snaking" action and the repetitive results indicated control.

It is apparent that, if the plate is mounted in a manner which permits freedom of motion, the tendency for errors will be minimized. If the plate could be firmly secured at a single point in the center, which would be a neutral

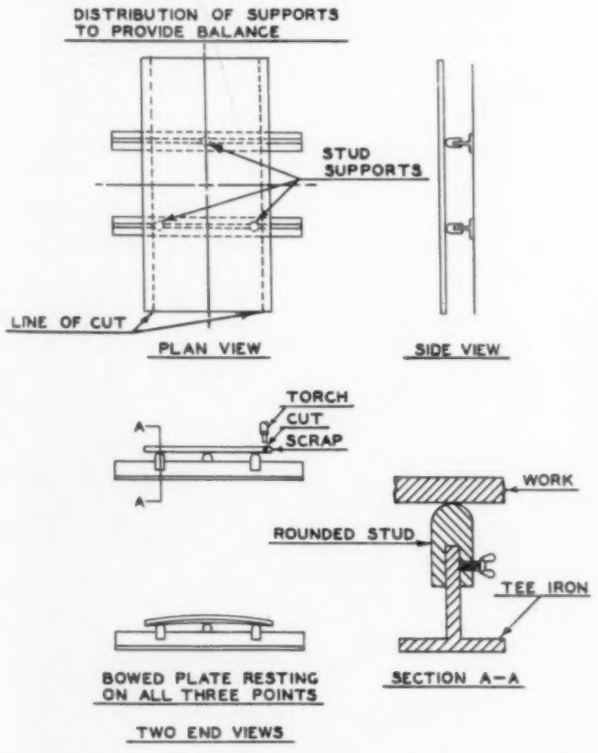

Fig. 10—Method of Providing Plate Support to Permit Freedom of Motion

point, any local disturbances would affect only slightly, if at all, other portions of the plate. However, this is obviously impractical and at least three points of support must be provided, the exact number depending largely upon the specific shape. With these points located inside of the line of cutting and with the support smooth and rounded to introduce a minimum of resistance to motion, the plate can still shift locally, and any rotative tendency will be eliminated. Such a type of support is suggested in Fig. 10. This type has the advantage of being easily moved to the desired location since the stud section can be moved on the tee shape. An additional advantage is that the support can be moved from the line of cut, which eliminates interference with the cut and unnecessary waste of supporting material.

The general practice of plate support has been to provide tee shapes in large number to insure that the plate will rest on something. Where this tee shape is of iron and the cut is made over it, the support soon becomes mutilated as shown in Fig. 11. This mutilated

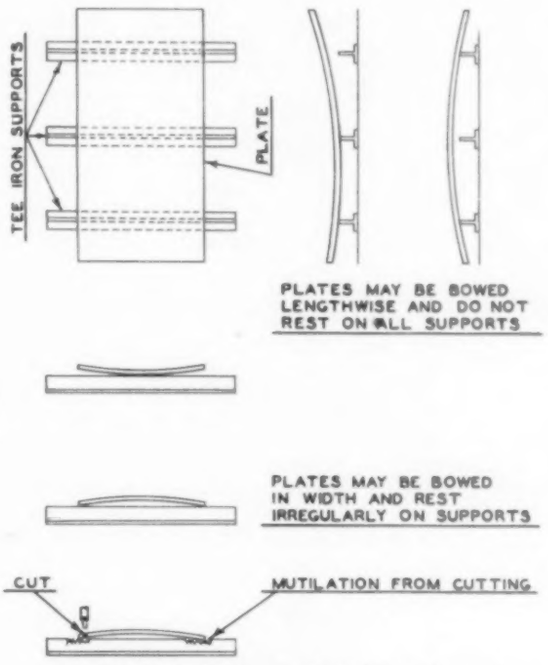
TEE IRON SUPPORTS
PLATE
PLATES MAY BE BOWED LENGTHWISE AND DO NOT REST ON ALL SUPPORTS
PLATES MAY BE BOWED IN WIDTH AND REST IRREGULARLY ON SUPPORTS
CUT
MUTILATION FROM CUTTING

Fig. 11—Plate Contour and Effect Upon Supports

section may catch the edge of the plate, setting up a condition which should be avoided. Also, the cutting action may introduce a slag bond between plate and support. It might be assumed that the support can slide, but this is not necessarily true since the frictional condition between the support and the table base is indeterminate and may withstand greater forces than the point of bearing between the plate and tee. In some cases, the support includes a non-ferrous surface for the plate to rest on. This design will eliminate the mutilation from cutting, but the soft material is easily damaged. As a rule, plates are bowed slightly, and the corners may dig into the support as indicated in Fig. 11, thereby restricting free motion.

The general problem of mounting the plate has been shown to be a very important factor if accuracy is to be obtained. The supports must be more than just a load carrying arrangement and must provide for control of the inherent motion so that the cutting is not affected. Any arrangement of support which does not permit this control will introduce inaccuracies.

Accuracy of Cutting

A comparison of the accuracies obtained on the various plates used in this investigation discloses that the control applied must have been instrumental in improving results. However, to appreciate the matter of accuracy it is necessary to determine just how it is applied. The use of a straight edge held against a cut surface will determine the points of deviation for that individual edge (see Fig. 12). If more than one edge is flame cut, it is necessary to carry this check further. The two edges can be individually inspected for straightness, but this does not bring in the matter of parallelity of the edges. The real inspection should include both straightness and parallelity as indicated in Fig. 12. If a rectangular section is flame cut and is to be ground or machined to a finished section with truly parallel and straight sides, the maximum final dimension will be determined by the distance between the greatest inward deviations. Again referring to Fig. 12, the amount of metal which must be removed and the final maximum dimension can be determined. With this information at hand, the real degree of accuracy can be ascertained.

Applying this analysis to the plates shown on Fig. 9, there is a decided improvement of the bottom plate which was properly supported compared to the other two, since less metal would have to be removed to obtain the straight, parallel condition. The group comprising the first four plates disclosed deviations ranging from $^1/_{16}$ to $^3/_{16}$ in., an average of $^1/_8$ in. for individual sides, but for the combination of parallelity and straightness the range was from $^3/_{16}$ to $^9/_{32}$ in. The second group of six plates had deviations for the individual edges ranging from $^1/_{32}$ to $^7/_{64}$ in., averaging $^1/_{16}$ in., while for parallelity and straightness, this range was from $^3/_{32}$ to $^{15}/_{64}$ in., averaging $^9/_{64}$ in. For five out of six of this last group, the range was $^3/_{32}$ to $^5/_{32}$ in., and the $^{15}/_{64}$ in. above noted appeared to be an exception.

Aside from the accuracies involving straightness, there exist other conditions such as angularity, location of openings, or angular error of bevels. It is difficult to conceive how an exact angle can be obtained between a side and end made in continuous cutting, if during the course of the cut a slight rotation of the plate develops.

Likewise, an opening will be incorrectly located if the plate has moved prior to making the cut unless adjustment in plate or template location is made. Each of these specific problems requires a knowledge of conditions that are likely to exist, and with this at hand a procedure can be determined which will assist in establishing the control required and minimize the chance for inaccuracies.

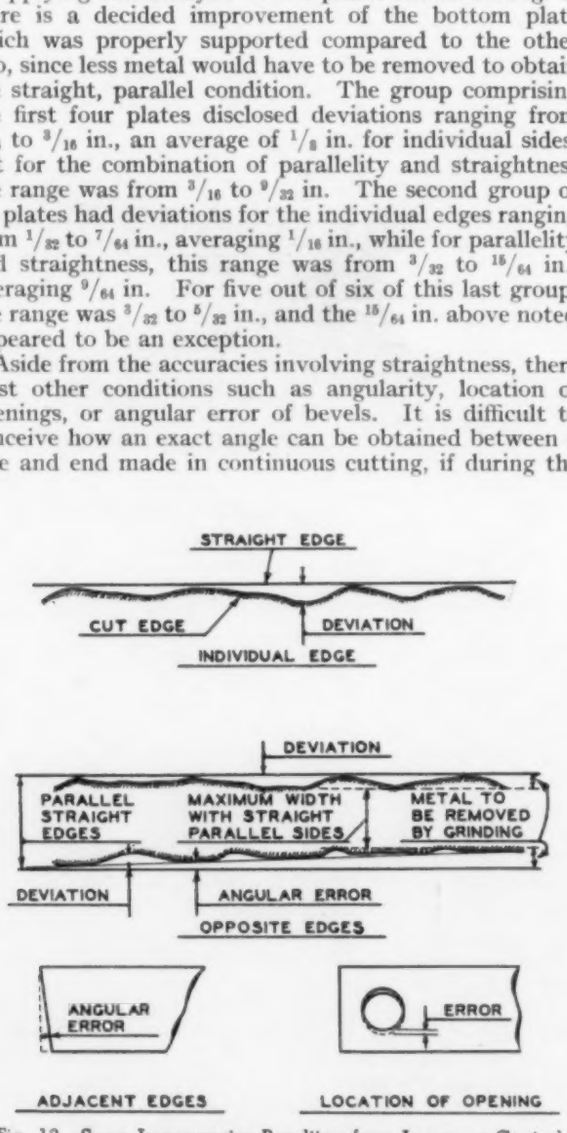

Fig. 12—Some Inaccuracies Resulting from Improper Control of Factors

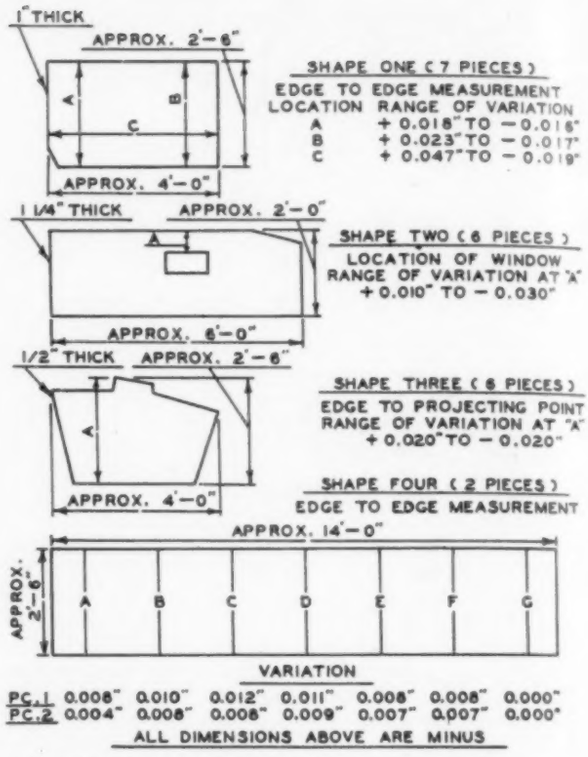

Fig. 13—Accuracy of Results Obtained in Production

Practical Applications

Although the foregoing results were obtained under conditions of careful control, equally satisfactory results are now being obtained in regular production. At one plant, a random check of a number of different representative shapes was made, limiting measurements to parallel sides. Use was made of a dial gage, bar and anvil to insure accuracy of measurement. A summary of the results is included in Fig. 13, as well as the general outline dimensions. The true shapes are not disclosed, but they included radii, notches and openings.

As a general picture, $\pm^1/_{32}$-in. tolerance will cover all but one dimension, while $\pm^1/_{64}$ in. will cover over one-half of the measurements. Shape IV is rectangular and about the same dimension as the plates used in the investigation. A comparison between this shape and Fig. 9 discloses far more accurate results for the former.

The procedure at this plant does not sacrifice production speed for accuracy. All equipment is kept in good condition, operating procedures are properly determined and consistently applied and templates are accurate and are carefully handled. The method of plate support has been given attention also, and all plates are mounted on rounded point supports. Scrap is removed if it interferes with the operation.

Other Factors

While attention has been focused upon the conditions existing within the plate while being cut, there also exist other factors which contribute to the accuracy or inaccuracy as the case may be. Some of these are controllable, some are not, and some involve fundamental knowledge often taken for granted. Through the years of growth of the mechanically operated cutting torch method of metal shaping, steady progress has brought about a better understanding of these factors.

The shape required is predicated upon the use to which a piece is put as well as the conception of the designer. Control of design thus assists in determining the ease with which a shape can be made or the possible accuracy that can be expected. While it is not expected that a designer know the intricacies of the torch cutting process, a rudimentary knowledge will prove valuable. No complete set of rules can be formed, but it must be recognized that the process involves a chemical reaction between iron and oxygen with a resultant heat effect. With this condition existing, narrow sections may pick up extra heat and not be capable of resisting warpage; thin plates may buckle or inadequate stock may not provide sufficient material for the reaction. Some thought devoted to the basic design and the recognition that unnecessarily close tolerances impose a restriction will materially aid in producing a good product.

The machine itself controls much of the accuracy, a condition common to all machine tools. Various types of machines are available, each designed to perform a definite type of work.

The selection of the type is dependent upon the nature of the work involved, and to expect a machine to produce results in a field beyond its scope is unreasonable. The choice of a particular design of machine with particular mechanical features involves workmanship, its capacity to stand up in use and its capacity to perform effectively the required functions. Where accurate cutting is a requisite, the mechanical principles must be considered from the standpoint of their inherent ability to consistently meet this requirement. Any construction which introduces irregularities of motion or permits excessive wear of parts can be expected to produce inaccurate results.

With certain types of machines which produce shapes by being guided from a template, a reproducing device is used. The accuracy with which this unit is capable of transmitting motion together with the accuracy of the template itself will enter into the results finally obtained. Any defect of the template will naturally be reproduced in the product. Therefore, care must be taken to provide templates which are basically accurate and of sufficient durability to maintain this accuracy.

The general type of equipment used to effect machine cutting does not involve heavy working parts or large forces when compared to much machine tool equipment, but nevertheless a reasonable amount of maintenance and care in use is necessary. Where a machine runs on a track, smooth operation can be expected only if dents and other defects are obviated. Since the process introduces pellets of slag and scale which will accumulate about the machine, inaccuracies can be expected if this foreign material lodges under the wheels or interferes with other working parts. Cleanliness and care in handling such items as the track or templates will do much to minimize irregularities of operation.

If the best results are to be expected, men with a reasonable amount of mechanical ability and general intelligence are essential. With this basic qualification, men will respond to proper instruction and supervision and can be relied upon to consistently do good work. However, the nature of supervision will be reflected in the results and here a knowledge of metal working as well as the general basic characteristics of the torch cutting process are as important as skillful manipulation of equipment.

The plate characteristics with regard to chemical analysis, surface condition and heat treatment enter into the operation. Most published data and operating procedure have dealt with ordinary low carbon steels of the structural type. It is recognized that these data do not always apply to alloy steels, but it has not yet been possible to predict just what specific conditions will prevail. As a basic consideration, carbon steel of the structural type contains 99% or more iron, which in combining with oxygen of very nearly 100% purity produces a reaction nearly free from impurities. Some of our alloy steels may contain as little as 90% iron or even less, the remainder being nickel, chromium, molybdenum, etc. In this case, the oxygen still combines with the iron and to a lesser degree with the other elements, but the other elements may act as impurities and retard the reaction. This results in a reduced cutting speed compared to the speed used with ordinary carbon steels.

The surface condition affects the execution of the cut since operating conditions must be set to function over the worst surface and this may not be best for all portions. Scale which contains oxides of the alloying elements as well as iron oxide may interfere with the preheat, the oxygen stream or the reaction so as to introduce erratic performance. Since it is not difficult to clean the surface by sandblasting or by flame cleaning, advantage should be taken to control this one factor.

The heat treatment of a plate does not appear to affect the cutting process in itself, but conditions which result from the treatment may. Upon being quenched, plates become warped and are subsequently flattened on presses. Internal stresses are thus created which affect the equilibrium of the plate when sections are removed. This change in equilibrium may produce plate motion, and there is no way of predicting the nature of the motion nor of controlling it.

While making a cut, the introduction of heat into the work creates local expansive forces on the order of 195 psi. for each degree rise in temperature. Assuming an average of 500 degrees temperature rise over a square inch of surface, this force will amount to almost 100,000 lb. This force is dissipated by an expansion of the plate and later as the plate cools it causes contraction. This condition of progressive expansion and contraction will cause changes in equilibrium and create plate motion. With plates containing internal stresses, the ultimate change due to the expansive force of the heat and the indeterminate force of the internal stress is likewise indeterminate. Where no pattern of regularity exists, no corrective allowances can be made. In some instances, however, it is possible to perform closed cutting so that the scrap portion sets up some balance of forces, although the application of this procedure is subject to a close analysis of the specific operation. Because of the forces involved, the application of restraining members to prevent plate motion is impractical in most instances, and may result in buckling or shifting of the plate.

Where machines embody templates and reproducing devices, allowances must be made for the width of kerf if close dimensions are required. Since the kerf results

from the oxygen stream, control of this stream is necessitated. This can be accomplished by establishing exact operating conditions and then by consistently applying them. Control also requires that a tip be kept clean and free from irregularities which will deflect the issuing oxygen stream. Any change of tip size, speed or flow that creates a kerf width different from that originally established will cause a different final dimension to be obtained.

In laying out various shapes to be cut from a plate and in determining the sequence of operations, each arrangement requires individual examination. Experience and observation will in time develop the best procedure to follow, but a general understanding of the many factors will guide the initial analysis along the most probable course. Certain initial steps in the setup are common practice such as leveling and squaring up. Even here the general process of cutting has, at times, shown the effects of rather careless training in the use of tools, and some operators overestimate their ability to obtain accurate alignment by visual inspection.

It is realized that the output will be affected if excessive checking is practiced. Therefore, the degree of accuracy desired will determine the degree of accuracy which can be applied in setting up.

Conclusion

While numerous factors exist which can affect the accuracy of the flame cut edges, of those which can be controlled the most important is that of maintaining the proper relationship between the plate, torch and guiding device. An understanding of the basic principles of the process, a knowledge and appreciation of good workmanship, a recognition of what is required and an analysis of what transpires while cutting are all necessary to obtain the best results. By application of this knowledge to introduce the necessary control of factors, there appears to be little reason for not obtaining accuracy equal to that of any other metal working process. In fact, it is remarkable that control can be applied to a chemical reaction and an issuing gas stream that makes possible the accurate results disclosed.

The Spot Welding of N-A-X High-Tensile Steel*

By C. R. Schroder†

THIS paper is written as a discussion report, and contains the information which was obtained during an investigation carried out at the Welding Research Laboratory of Rensselaer Polytechnic Institute by the author and by Dr. W. F. Hess who is director of that laboratory.

The complete data and results of this investigation have been published as two articles in the April and May (1942) issues of THE WELDING JOURNAL, and readers are referred to these publications as a complete source of the data and information upon which the conclusions and statements of this paper are based.

Previous to this investigation, high-tensile and deep hardening steels had been reported as very difficult to spot weld, in comparatively thin gages, by the ordinary methods of single and multiple pulse welding as used for plain low carbon steels. The difficulty arose from the fact that the cooling rate of spot welds made on thin gages is of such magnitude as to result in a very hard and brittle weld structure for steels of considerable hardenability. This brittle structure, like all brittle metallic structures, exhibits a high resistance to shear stresses, but is very low in resistance to normal stresses, and hence these welds break apart very easily when subjected to stresses, which are normal to the welded surface. It was found that this brittle weld structure was obtained when the welding heat was developed in a single pulse, or when the welding heat was developed as a result of a series of successive pulses which is commonly known as pulsation welding. This was as expected, since in the case of thin gages, even though the welding heat be developed by more than one pulse, the cooling rate from the molten state would be high enough to result in a very brittle structure.

In the course of this investigation a very successful method was found for spot welding the N-A-X high-tensile steel used in this work, and it is reasonable to suppose that this method, with necessary but minor adjustments for steel chemistry, thickness and hardening characteristics, can be applied to other steels of medium and even high hardenability.

Briefly, the method consists of making the weld in a single pulse of as few cycles as necessary to result in a spot diameter consistent with electrode diameter; allowing a very critical and definite time off in which the weld cools quickly to form a brittle transformation product, and then drawing or tempering this brittle structure to one of far greater toughness and ductility by means of a second pulse which we have termed a heat-treating pulse. This heat-treating pulse which consists of as few cycles as are necessary to obtain the desired result with a current magnitude which is usually considerably less than that required in the actual welding pulse.

The total time required for the weld, time-off and heat treatment is about 25 cycles ($^5/_{12}$ sec.) for 0.040-in. material, and about 50 cycles ($^5/_6$ sec.) for 0.070-in. material. The entire cycle of weld, time-off and heat treatment can be made in one contact of the electrodes with one setting of the electronic control equipment.

Welds made by this method in the high-tensile steel used in this investigation resulted in weld structures which were much softer, more ductile and of far greater toughness than the weld structures obtained in previous methods used for spot welding these thin gages of deep hardening steels. It was found that by using this method, the actual ratio of U-strength to shear strength for a spot weld in this material could be more than

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† Research Metallurgist, Great Lakes Steel Corporation, Detroit, Mich.

doubled as compared with that ratio for welds made by ordinary methods without a post heat-treatment cycle. This ratio of U-strength to shear strength may be considered as an accurate indication of the toughness or ductility of a spot-weld structure since it is a measurement of the ratio of the resistance to normal to the resistance to shear stresses. When this ratio is high, which means the structure has a high ratio of normal strength to shear strength, it is a good indication that the structure is tough and ductile.

Thus it seems that, even with the slight increase in time required by using this method, if the ratio of U-strength to shear strength can be increased from within the range of 20 to 30% to within the range of 50 to 60%, the method is certainly practical. For plain low carbon steels, welded by ordinary methods, this ratio is usually in the range of 50 to 70%, and if methods can be used for high-tensile and deep hardening steels, which methods will result in ratios which are nearly as high as those of the plain low carbon steels, then the advantages are clearly evident. The actual shear and U-strength values for the high-tensile and deep hardening steels are much higher than those obtained for plain low carbon steels.

The method developed and used in this work has resulted in weld structures of sufficient combined strength and ductility or toughness to compare favorably with the properties of the parent metal in which the welds are made.

It is also recognized that most of the extra time required by this method can be saved again by improved methods of material handling in production welding operations.

Material and Equipment

The N-A-X high-tensile steel used in this work, and for which this spot-welding method has been developed has the following analysis:

Carbon	0.14	Silicon	0.84
Manganese	0.65	Chromium	0.57
Phosphorus	0.017	Molybdenum	nil
Sulphur	0.021	Zirconium	0.11

This steel is one of series of N-A-X high-tensile steels, and its physical properties in sheet form are as follows:

	Annealed	Half-Hard
Tensile strength, psi.	70,000	98,000
Yield point, psi.	50,000	90,000
Per cent elongation, 2 in.	28	....

This investigation included work on two thickness of the above material in both the annealed and half-hard tempers. The article appearing in the April 1942 issue of THE WELDING JOURNAL includes the work on the 0.040-in. material of both annealed and half-hard tempers, and the following article appearing in the May issue includes the work on the 0.070-in. material of both annealed and half-hard tempers. A discussion of the information contained in both articles is included in this paper.

"For the present investigation we were fortunate in securing the cooperation of the engineers of the General Electric Company in developing a panel which permits accurate control by fully electronic means of the following time intervals:

1. Time of weld.
2. Time between weld and heat treatment.
3. Time of heat treatment.

In addition to the accurate time control the equipment provides independent adjustment by means of phase control, of welding current and heat-treating current. By means of this flexible control equipment, the proper conditions for producing welds in hardenable steels have been developed. Such control equipment may easily be made commercially available at only a moderate increase in cost over ordinary spot weld control equipment with phase control of welding current. For production work in the shop it is possible that a very simple mechanical timing system, such as the chain timing equipment which is now on the market, may be used. This equipment requires a few minutes to change welding conditions but it appears that the timing intervals may be definitely set up for particular gages, and these timing conditions may then remain unchanged as long as the gage of material is the same. For experimental work in the research laboratory, or where the type of work in commercial production is very frequently changed, the electronic equipment makes possible more rapid change in timing conditions."*

0.040-In. N-A-X High-Tensile Steel

The results obtained, as a result of investigation carried out on the material of 0.040-in. thickness will be discussed first. Here again the reader is referred to the April 1942 issue of THE WELDING JOURNAL. The subject article in this publication contains the complete figures, tables, curves and data pertaining to actual welding conditions. The following effects will be discussed in order:

1. Effect of weld size.
2. Effect of interval between weld and heat treatment.
3. Effect of magnitude of heat-treating current.
4. Effect of time of heat treatment.

Effect of Weld Size

During the early part of this investigation it became apparent that, for spot welds of medium diameter, an increase in spot diameter was accompanied by a definite corresponding increase in the U-strength to shear strength ratio. This was found to be true even when the welds had no subsequent post heat treatment in the welding machine. The U-strength increased more rapidly than the shear strength for increasing weld diameters, up to a maximum diameter, above which there was little or no increase. This diameter above which no appreciable increase in U-strength to shear strength ratio was found for an increase in weld diameter, was taken as the minimum or optimum spot diameter to be used in the investigation of the effects of post heat treatment. For the 0.040-in. material, both in the annealed and half-hard tempers, this minimum diameter was found to be about 0.210–0.220 in., and was obtained by using $^1/_4$-in. flat tips.

When the spot diameter was only 0.150 in., using $^3/_{16}$-in. flat tips, the ratio of U-strength to shear strength obtained was about 10% for an as-welded specimen using no subsequent heat treatment. This ratio could be increased to about 30% for an identical as-welded specimen, using $^1/_4$-in. flat tips which gave a spot diameter of about 0.220 in.

It is evident that, if the spot diameter were lowered to a value considerably below 0.150 in., a diameter would be found at which the ratio would again increase to a

* Hess, W. F. and Schroder, C. R., "The Spot Welding of N-A-X High-Tensile Steel," THE WELDING JOURNAL, 21 (4), Research Suppl., 203-s to 208-s (1942).

very high value, since the weld would be entirely too small and would have a very low U-strength but also a very low shear strength. The ratio would be high, but the actual strength values would be very low. Such welds, of course, would be of no practical value.

Effect of Time Interval Between Weld and Heat Treatment

The time interval between weld and heat treatment was found to be a very critical and important factor in increasing the toughness of spot welds by means of post heat treatment in the welding machine. It was found that, for a weld made under given conditions, there exists a critical minimum time, during which the weld must cool to below the martensite forming temperature, before the complete advantages of the heat-treating cycle can be obtained. Although no definite critical maximum time between weld and heat treatment was found to exist within reasonable limits, still, practical reasons alone dictate that the minimum time with a slight safety factor should be adhered to. This is also consistent with sound metallurgical practice since drawing or tempering a fully quenched transformation product as soon as possible after the quench has its well-known advantages.

This critical time interval between weld and heat treatment was found to be about 12 cycles ($^1/_6$ sec.) for the 0.040-in. material. For constant welding conditions, time of heat treatment and heat-treating current, the ratio of U-strength to shear strength could be doubled as this critical time interval was increased from 10 cycles to 12 cycles. In fact, as this time between weld and heat treatment is lowered to a value below 10 cycles, the actual ratio of U-strength to shear strength drops below the as-welded ratio. The reason for this will be discussed under the section covering the investigation of the 0.070-in. material, for it was during this latter investigation that the reasons for this observed characteristic became more apparent by a correlation of Vickers hardness surveys across the weld, and changes in ratio of U-strength to shear strength.

Hardness surveys were taken in all cases, and, with proper heat-treating procedure, the expected drop in hardness of both weld and heat-affected zone was noted, with increasing weld toughness and increasing ratio of U-strength to shear strength.

The investigation of the time interval required between weld and heat treatment for the 0.040-in. material gave indication that the cooling rate, for spot welds made under the conditions of this work and in the material of 0.040 in. thickness, was in the neighborhood of 7000–10,000° F./sec. between the melting point and the martensite forming temperature. This makes evident the fact that to arrest the cooling at a definite temperature level and holding to give an isothermal transformation product would be very difficult in material of this thickness. It is understood that the possibility exists whereby spot welds made in thick gages, and consequently having a considerably slower cooling rate, may be successfully transformed at constant temperature in the welding machine.

Effect of Magnitude of Heat-Treating Current

Since the critical time interval between weld and heat treatment was found to be about 12 cycles, a safety factor of 2 cycles was allowed, and the other effects of heat-treating current and time of heat treatment were investigated by holding the time between weld and heat treatment constant at 14 cycles.

The magnitude of the heat-treating current was found to vary inversely with the time of heat treatment. This would be expected. However, it was also found that the optimum value for magnitude of heat-treating current became far more critical with both comparatively short- and long-time heat treatments. The shortest time of heat treatment investigated was 2 cycles and the longest time investigated was 60 cycles. As the magnitude of the heat-treating current approaches an optimum value for a given time of heat treatment the weld structure begins to soften from the center out toward the edge, and when the optimum value of heat-treating current has been reached the junction of weld and heat-affected zone has been softened to the greatest extent possible by this method, and the center of the weld may begin to show rehardening as the heat-treating current is increased to values above the optimum then definite rehardening takes place. Slight rehardening at the center of the weld does not lower the U-strength to shear strength ratio and does not offset the beneficial effects of the heat treatment. In many cases a slight rehardening of the weld center was necessary to give a minimum softness at the weld-heat zone junction, which resulted in the highest U-strength to shear strength ratios. If, however, the rehardening has spread far enough to begin to affect the above-mentioned weld-heat zone junction, then all beneficial effects of the heat treatment are lost. With the proper time interval between weld and heat treatment, and the proper heat-treating current and time of heat treatment, the weld structure including the heat-affected zone can be softened from about 420–440 V.P.N. as welded, to about 280–300 V.P.N. as welded plus heat treatment in the welding machine. This, of course, applies to the 0.040-in. N-A-X high-tensile steel used in this investigation.

For heat-treating times of approximately the same number of cycles duration as the actual welding time, it was found that the optimum value of heat-treating current was not too critical. The values of heat-treating current were always plotted as percentage of welding current, since this percentage remained fairly constant for definite conditions producing similar results, whereas the actual heat-treating and welding amperage values may vary considerably. This would be an expected observation, since the spot diameter or weld size will vary directly with the welding amperage for a given electrode tip diameter, and the actual heat-treating amperage required to produce given results will also vary directly with weld size.

Effect of Time of Heat Treatment

As before mentioned, the magnitude of heat-treating current is closely associated with the time of heat treatment, and becomes more critical with comparatively long and short times of heat treatment. The range of heat treatment time investigated was from 2 cycles to 60 cycles. For practical reasons, the heat-treating time should be kept as low as is consistent with desired results and current flexibility. It was found that a heat-treating time of approximately the same number of cycles duration as the welding time gave sufficient softening and toughening of the weld structure, with optimum current values which were not too critical for ordinary electronic controlled welding machine operation.

For very short-time heat treatments the current must be adjusted so as to give maximum softening at the weld-heat zone junction, and rehardening will be found at the center of the weld. Since the time is very short and the current value high, a slight increase in current

will result in spreading the rehardened area to the weld-heat zone junction, and a slight reduction in current will not produce enough heat to soften this junction. When the time of heat treatment is long, the corresponding optimum heat-treating current is comparatively low, and a slight increase or decrease in current value will produce the undesirable results above mentioned. Thus the magnitude of the heat-treating current is far more critical with very long or very short heat-treating times.

Microscopic Examination

The as-welded microstructure, with no subsequent heat treatment, is extremely hard and brittle. The hardness, as measured by the Vickers method, is in the range of 420–440 V.P.N. This is certainly hard for 0.14 carbon steel. This structure has been termed martensite throughout this investigation, although the microscope does not show it to be exactly the same in appearance as typical as-quenched martensite of ordinary heat-treating practice. This difference can possibly be attributed to the fact that this weld structure has been quenched from the molten state at a rate which is very much higher than that associated with ordinary heat treatment, and under a pressure of 1500 atmospheres.

The microstructures of specimens which have been welded and subsequently heat treated in the welding machine are more clearly defined, exhibit faster and darker etching characteristics and resemble closely the quenched and drawn structures which are obtained from ordinary heat-treating practice with this type of steel. The as-welded structure required an etching time of from two to three minutes with a 5% picral solution, whereas the quenched and drawn structure required an etching time of one minute with the same solution.

0.070-In. Material

For complete data, figures and results obtained during the investigation of the use of this type of spot welding for 0.070-in. gage N-A-X high-tensile steel, the reader is again referred to the before mentioned publication appearing in the May 1942 issue of THE WELDING JOURNAL.

The investigation of the 0.070-in. material has more clearly defined and confirmed the general results obtained, and so far discussed, with respect to the 0.040-in. material. Of course, the electrode size, pressure, welding time, time interval between weld and heat treatment, time of heat treatment, welding amperage and heat-treating amperage are all expected to vary with variation in material thickness.

For the 0.070-in. material it was found that the critical minimum time interval which must be allowed between weld and heat treatment is about 32 cycles. It was again found that the ratio of U-strength to shear strength, for welds, which were heat treated after a time interval of less than 32 cycles, was lower than the ratio obtained for welds receiving no heat treatment at all. The explanation for this is evidenced by a correlation of the hardness surveys across the weld structures, including the heat-affected zones and the parent metals.

Photoelastic studies have shown that, in the U-type tensile testing of a spot weld, the maximum stress concentration is located at the heat-zone to weld junction. For spot welds made by ordinary methods without subsequent heat treatment in plain low carbon steel, there is very little hardness gradient between weld and heat-zone, and between the heat-zone and parent metal. The entire structure is comparatively soft and ductile. These welds, in plain low carbon steels have high U-strength to shear strength ratios. For welds made without subsequent heat treatment in high-tensile and hardenable steels, there exists a steep hardness gradient from parent metal to heat-zone with little hardness gradient from heat-zone to weld. The weld and heat-zones may be very hard and brittle, but having little hardness gradient across their junction. They will exhibit comparatively low U-strength to shear strength ratios; however, much of the stress is probably concentrated at the parent metal to heat-zone junction as a result of the steep hardness gradient across this junction. This means that the stress concentration is divided between the parent metal to heat-zone junction and the heat-zone to weld junction. The first stress concentration is a result of hardness gradient, and the second stress concentration is a result of notch effect which is inherent to this U-type of normal test.

For welds made with subsequent heat treatment in high-tensile and hardenable steels, but in which the time interval between weld and heat treatment has not been long enough, the heat-zone is greatly softened and the weld remains very hard. This means that the entire stress concentration, resulting from notch effect and hardness gradient, acts on the heat-zone to weld junction. This junction is inherently sensitive to normal stress since it is the origin of the ingrowing dendrites. Thus, a weld heat treated without sufficient time interval between weld and heat treatment, will have extremely low resistance to stresses which are normal to the welded surface, and will snap apart in a very brittle fashion, and at low loads, in the U-type tensile test. These welds exhibit even lower ratios of U-strength to shear strength than welds made properly but with no subsequent heat treatment whatsoever.

When the weld is properly made, and heat treated after sufficient time interval between weld and heat treatment, both the heat-zone and weld have been softened with little or no hardness gradient across their junction. These welds exhibit a ratio of U-strength to shear strength which is double the value obtained for welds given no subsequent heat treatment.

If the heat treatment rehardens the center of the weld, it will not appreciably lower the U-strength of the weld provided the rehardened area does not approach the heat-zone to weld junction. This junction is the all-important area, and heat treatment should be directed at softening the heat-zone and the first 0.02 to 0.04 in. of the outside of the weld area, giving little or no hardness gradient across this junction.

The critical time interval between weld and heat treatment was found to be 32 cycles for the 0.070-in. material, as compared with 12 cycles for the 0.040-in. material. The difference is considerable; however, the values are in fair agreement with mathematical prediction that the cooling rate of spot welds varies inversely as the square of the thickness.

In working with the 0.070-in. material, the effect of using refrigerated coolants was studied, with respect to lowering the time interval required between weld and heat treatment. During the entire investigation, the coolant temperature had been about 18° C., and it was found that lowering this coolant temperature to 3° C., decreased the time interval by only 2–3 cycles. This means that coolants would have to be refrigerated to very low temperatures in order to result in an appreciable saving in time, which means the sometimes ill effects of water condensation and frosting on the electrode tips, plus the cost of refrigeration, would have to be balanced against the economics of a possible increase in production speed.

The optimum spot diameter for the 0.070-in. material was found to be about 0.310 to 0.320 in. As in the case of the 0.040-in. material it was found that the advantages of heat treatment could be obtained in a few cycles heat-treating time. The optimum time for heat treatment, with respect to current flexibility and sufficient weld area softening, was found to be about 8 cycles for this 0.070-in. material. The optimum welding time for the 0.070-in. material was also 8 cycles.

Summary

1. Remarkable improvement in toughness of the spot welds in hardenable steels is possible by brief heat treatment in the spot-welding machine, following welding. This appears to open a new field of spot welding, in those steels in which spot welds are ordinarily hard and brittle.

2. The mechanism of the toughening consists of allowing a drastic quench to martensite followed immediately by a high draw at a temperature just below the critical.

3. A time of from 2–5 cycles is sufficient to secure the maximum benefit of post heat treatment in the gages and steel of this investigation.

4. Sufficient time must be allowed for the steel to cool to the martensite-forming temperature, as otherwise the reheating accomplishes nothing. In order to reduce the time required for cooling, the weld should be made in the shortest possible time. This is due to the fact that the more rapidly the weld is heated and made, the less total heat is required and consequently the more rapid the cooling. This will permit reasonable total weld plus heat treatment time, and thus not tend to limit production speeds.*

5. The heat-treating current must be carefully adjusted to raise the temperature as high as possible without reaching the critical transformation temperature.*

6. The chisel test is a practical shop method of determining the proper magnitude of heat-treating current. Hardness tests at the center of weld cross sections for a series of welds with progressive variations in heat-treating current, will select the best value with greater certainty.*

7. With respect to the 0.070-in. material, lowering the coolant temperature from 18 to 3° C. will reduce the time interval required between weld and heat treatment, by only 2–3 cycles—from 32 cycles to about 30 cycles.

8. The general procedure and method used in this investigation could probably be used to greatly improve spot-weld quality in all types of low alloy high-tensile, high carbon and deep hardening alloy steels. It must be remembered, however, that all-steel characteristics with respect to chemistry, carbon content, amount of contained alloy, hardenability, S-curve characteristics and reactions to drawing temperatures and procedures will undoubtedly affect spot-welding variables such as time of weld, welding amperage, time interval between weld and heat treatment, time of heat treatment, heat-treating amperage and the extent of the critical range of these welding variables. The actual figures and data obtained for this N-A-X high-tensile steel will not necessarily be correct for other types of similar steel, however, the general method of post heat treatment in the welding machine shows great promise for future improvement of spot welds made in thin gages of hardenable steels.

Acknowledgments

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(*Continued from page 675*)

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ANNUAL MEETING

American Welding Society, Hotel Cleveland, Cleveland, Ohio
October 12–15, 1942

Plan to Attend!

High-Quality Welding In Vertical and Overhead Position with Alternating Current*

By H. O. Westendarp, Jr.†

THE purpose of this paper is to direct attention to what is probably one of the most important developments in the welding industry in the year 1942, and a development which has direct bearing on the war effort. Before presenting specific data on the development itself, it will perhaps be interesting to review briefly the history of a.-c. welding progress.

Mr. C. J. Holslag, one of the pioneers of the welding industry, conducted experimental welding with alternating current around the beginning of the first World War. At that time heavy coated electrodes were not readily available and, due to the inherently low arc stability of bare electrodes, it was practically impossible to produce successful arc welds with them on alternating current.

From a production standpoint, the a.-c. process could certainly not compete with direct current, since even highly skilled operators could not strike the arc easily and maintain it uniformly when using the a.-c. electrodes and equipment that were available at that time. Consequently, d.-c. welding established itself firmly in many classes of work and was generally conceded to be the way to produce a successful arc weld.

During the first World War, however, alternating current welding obtained serious recognition in this country as a coming welding process. Electrodes having light lime coating for arc stabilization had been developed and produced. These were followed by the development and production of the sheathed type of electrode having a solid core, a film of flux and an outside metal sheath. Even with this stabilizing effect as created by these light types of coating, a relatively high open circuit striking voltage was required (approximately 100 volts). The apparatus available at that time was relatively crude, some types of equipment having the welding circuit tapped off the main power supply circuit. The insulation that was used on some of the earlier types of transformers was somewhat questionable. Secondary terminals of welding transformers were exposed. In the event of insulation failure, it was possible for the operator to receive contact with the primary voltage.

Shortly after the first World War the heavily coated type of electrode was developed and produced in this country, although it had been available in limited quantities from Europe prior to that time. Since d.-c. welding was the established and preferred method, the development of heavily coated electrodes was carried on with this in mind. It is interesting to note that there was frequently some doubt as to whether an electrode should be used on straight polarity or reverse and the best polarity for an electrode was often determined only by actual test. This naturally led to experiments with alternating current.

It was immediately apparent that many straight polarity d.-c. electrodes could be used successfully on a.-c. circuits with relatively high open circuit voltages. This pointed the way to one of the primary objectives in the design of a.-c. electrodes—the improvement of inherent stability of arc to permit easy striking and maintenance of the arc with an a.-c. circuit of reasonable open circuit voltage. One of the first widely used straight polarity d.-c. electrodes, for example, required a voltage of at least 100 volts when used on alternating current, whereas many good a.-c. electrodes are available today that can be operated on 65- to 70-volt circuits. As a result of the rapid development of suitable heavily coated types of electrodes for use with alternating current, this

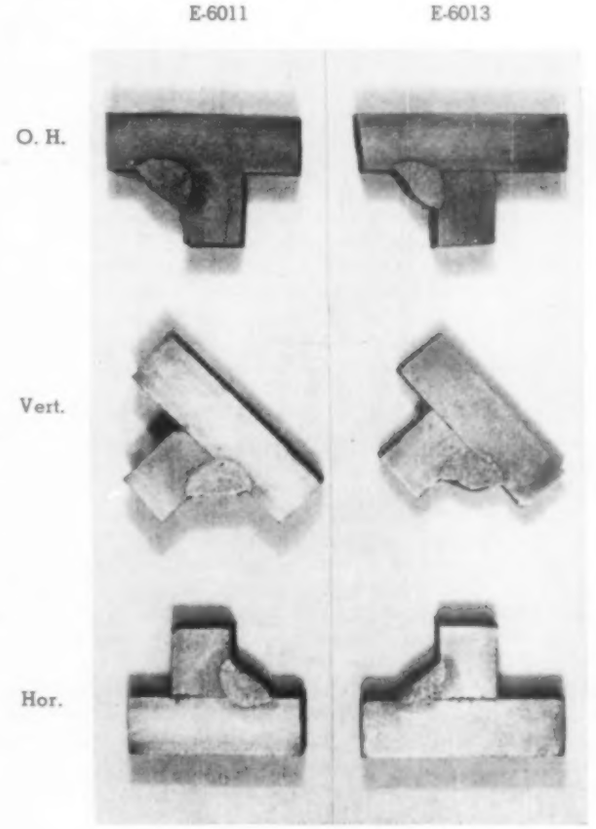

Fig. 1

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† Industrial Department, General Electric Co., Schenectady, N. Y.

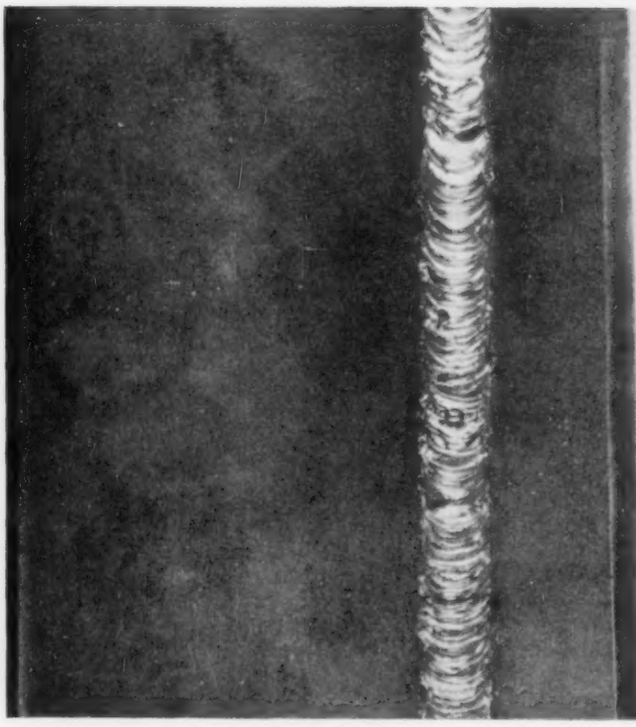

Fig. 2—E-6013

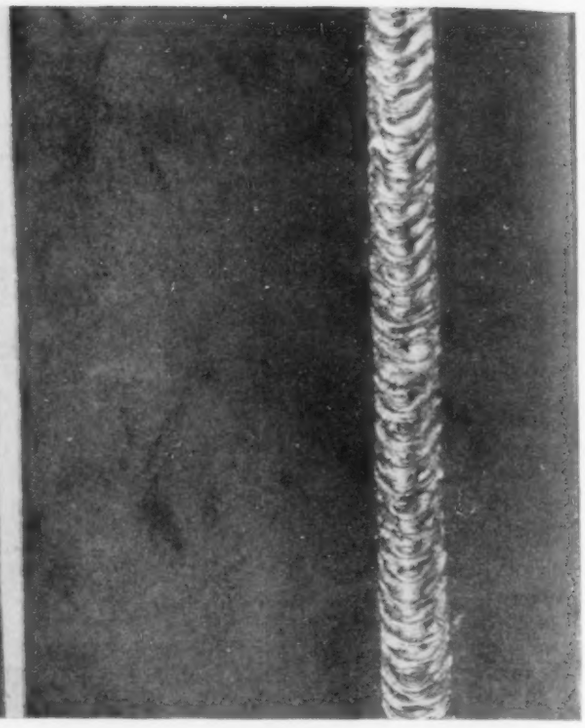

Fig. 3—E-6011

process of arc welding gathered considerable speed in the early 30's, although it was hampered somewhat by the fact that improvement was needed in a.-c. equipment design. This was the next step with the result that a.-c. welding transformers of the insulating type and other highly refined designs of a.-c. welding equipment were developed and produced for general use by industry. These modern equipments eliminated the electrical hazards formerly existing in earlier designs by completely separating the secondary from the primary circuit and by utilizing reasonable ranges of open circuit voltage, and in combination with the modern types of heavily coated electrodes, made available to the welding industry the now well-recognized benefits inherent in the a.-c. process. We are briefly reviewing these benefits as follows:

Arc Blow.—Alternating-current welding reduces magnetic disturbance of the arc (arc blow) to a point that it is seldom, if ever, troublesome to the operator. This is the biggest single advantage of a.-c. welding. Whereas troublesome arc blow does not always exist with direct current, still there is hardly a job to be done or a day that goes by that a d.-c. welding operator will not get up against the problem of fighting arc blow, and in some types of work it is an almost continuous deterrent to production of high quality welds on a production basis.

It is quite well recognized that arc blow from the d.-c. circuit increases with welding current, or, conversely, that it is advisable to limit the welding current when welding under conditions where arc blow is troublesome. Alternating-current welding permits the use of higher welding current in many types of work and in some cases it is possible to increase the diameter of electrode used as well as the welding current with a net result of a decided increase in welding speed. Alternating-current welding, therefore, does increase production in certain types of work, particularly where fillet welding in corners is required.

Power Consumption.—Our power plants are being taxed to the limit to meet the demands of the war program. Kilowatts are at a premium. The use of alternating current immediately cuts the kilowatt-hours required for arc welding. The saving is big and is, of course, due to the inherently high efficiency of transformers compared to rotating equipment. The elimination of windage and friction and no-load losses represent a material saving in kilowatt-hours. Total power savings vary with different types of work, but for shipyards the saving is approximately 45%. For tank fabrication the saving is approximately 35%. For gun mount fabrication the saving is approximately 35%. Alternating-current welding, therefore, helps to break the bottleneck in power supply.

Maintenance and Repair.—Under today's conditions, it is particularly important that all equipment be operating 24 hours per day and 7 days per week. The inherent simplicity of a.-c. transformer design is a definite step to this end. There are no wearing parts, and the amount of attention for lubrication and cleaning is reduced to a minimum.

Production and Conservation.—These are two vital points which we all must keep in mind today. Alternating-current welding transformers can be turned out in large volume quickly. Furthermore, they require only approximately 60% of the amount of copper per ampere that is required for the production of d.-c. welding equipment. While having no direct fearing on the subject, we bring it to attention, since procurement is a vital question with which we are all now confronted.

The foregoing brings us up to the year 1941. Direct-current welding had been established quite firmly in many fields, ranging from production to maintenance and repair of innumerable products. Alternating-current welding was gathering speed, particularly since the availability of improved design equipment and heavily coated electrodes which were now being produced in increasing quantities. However, there was still one bottleneck to the forward progress of a.-c. welding—*the problem of producing a high-quality weld in the vertical and overhead position with alternating current still remained unsolved.*

Alternating-current electrodes suitable for welding in the vertical and overhead positions were available, but the deposited metal from such electrodes would not meet the AMERICAN WELDING SOCIETY Specifications A-233-40T, Class E-6011, or the requirements of other authoritative regulatory bodies.

Electrode development laboratories, recognizing the importance of such a development, were working furiously in an effort to develop such an electrode. This development was consummated and put into production the early part of this year and now makes the inherent advantages of a.-c. welding generally available to industry.

Physical Properties.—Table 1 shows a comparison of the physical values of deposited weld metal between A.W.S. Class E-6010, E-6013 and the new E-6011 electrodes.

An examination of these data clearly indicates that the new a.-c. electrode, Class E-6011, not only passes the requirements of ductility with an ample margin, but does so at an exceptionally high yield point and ultimate tensile strength. Due to the short time this electrode has been available, the amount of experience obtained has, of course, been limited, but it is evidently very well suited to the welding of many high-tensile low-alloy steels, due possibly to the combination of high yield point and ultimate tensile strength with high elongation as indicated in the tabulated data.

Radiographic Properties.—Classes E-6010 and E-6011 electrodes produce deposited weld metal practically free from any porosity and easily meet the requirements of A.S.M.E. Boiler Code, Paragraph U-68, and Navy Bureau of Ship Specifications 46E3, Grade 3, Class 1. Class E-6013 electrodes produce deposited weld metal which generally shows fine spray scattered porosity inclusions in limited quantity inherent in this type of deposit.

Penetration and Contour.—Figure 1 shows a comparison of penetration and contour characteristics of fillet welds produced by A.W.S. Class E-6013 and A.W.S. Class E-6011 electrodes in horizontal, vertical and overhead positions. The excellent penetration and comparatively flat fillet welds produced by the new Class E-6011 electrode is readily apparent. This, of course, results in added strength of fillet and conservation of scarce electrode material. Although pictures do not indicate it, there has been a slight tendency for undercutting on the vertical leg of horizontal fillet welds made from certain of the Class E-6011 electrodes available. This is a problem which is being given very careful attention by the Electrode Development Laboratories at the present time. It will be noted that the vertical and overhead welds for which Class E-6011 electrodes are specifically designed show a decided advantage over a.-c. electrodes formerly available. Horizontal fillet welds with alternating current would normally call for A.W.S. Class E-6020 electrodes.

Figure 2 shows appearance of face of weld made in vertical position with Class E-6013 electrodes. Figure 3 shows the appearance of face of weld made in vertical position with Class E-6011 electrodes. Both welds were made with arc progress from bottom up.

Arc Action.—The arc action of Class E-6011 electrode is forceful and digging as compared to the relatively soft arc inherent with the Class E-6013 type. The new a.-c. Class E-6011 electrode is, therefore, similar in arc action to the reverse polarity d.-c. Class E-6010 type of electrode. Recommended arc-welding current and voltage ranges of Class E-6011 electrodes are practically identical to the recommended ranges of the reverse polarity d.-c. Class E-6010 type. Welding technique is also very similar. Since recommended current and voltage ranges and welding technique may vary slightly with different makes of Class E-6011 electrodes, no specific recommendations are made on these points.

Table 1—Physical Properties of Deposited Weld Metal

A.W.S. Class Welding Current	E-6013 (A.C. or D.C.)	E-6010 (D. C. Only)	E-6011 (A.C. or D.C.)
Spec. requirements			
Ult. ten. st., psi.	65,000	65,000	65,000
Elong. % in 2 in.	17	22	22
Typical results			
Ult. ten. st., psi.	72,000	67,000	72,500
Yield point, psi.	58,000	55,000	60,000
Elong. % in 2 in.	20	25	27
Charpy impact, ft./lb.	27	30	34

All results "as welded."

How Does the Above Development Affect the War Effort?

Today's conditions require that most work be done to specifications. These specifications very properly set certain minimum limits of physical requirements of deposited weld metal, such as ductility, yield point, ultimate tensile strength, etc.—whether the product be a ship, a tank or a gun mount, or other ordnance material.

Contractors and sub-contractors to the Government, doing work under specifications calling for high quality welding, not only in flat but also in vertical and overhead positions, have heretofore either been compelled to use d.-c. welding entirely, or switch from a.-c. welding when doing work in the flat position, to d.-c. welding when doing work in the vertical and overhead position.

Benefits to be derived from a.-c. welding are of such importance as to practically compel its use in flat position, yet much time has been lost due to the necessity of changing from alternating current to direct current in order to take care of the vertical and overhead requirements.

In some cases, plants have sacrificed the benefits to be derived from a.-c. welding, such as increased production, reduction in power consumption and maintenance and repair bills, and standardized completely on d.-c. welding equipment, due to the lack of a high-quality a.-c. vertical and overhead electrode.

The development of the new Class E-6011 electrode, therefore, extends the inherent advantages of the a.-c. process to all positions of welding. This should be and is being taken into consideration in the design of all new welderies.

The availability of this new Class E-6011 electrode will also immediately solve many problems in existing plant installations, since it will permit the use of a.-c. welding equipment now being confined to work in the flat position only for the production of welds in all positions and release d.-c. units formerly held for the vertical and overhead work. The d.-c. units which are released can be used for other work, such as certain special types of steel or non ferrous metals, for which only d.-c. welding electrodes are available. This development consummated in 1942, therefore, gives the welding industry one more string to its bow in the battle of production.

Development in Cast-Iron Welding Rods and Electrodes*

By R. J. Franklin†

ALTHOUGH cast iron has been in prominent use during the period of the great expansion in the use of welding, its progress as related to welding has not been parallel to the progress made with the newer metals.

This condition probably arose from early attempts to weld cast iron which showed the metal unsuitable for fabrication and thereby restricted the use of cast-iron weld rods to repair purposes. As such there has not been the continuous pressure for improvement or the tightening of specifications that has occurred in the steel and alloy steel rods and materials used for fabricating purposes. When it was decided that cast-iron welding would have to be restricted to the repair of castings the property of cast iron that possessed the greatest interest was its machinability, as it was the lack of this property which quickly brought down criticism upon those who had done the repair work, as well as the manufacturers.

Current specifications covering cast-iron rods for oxyacetylene welding permit a carbon range of from 3.00 to 3.50% and a silicon range of from 2.75 to 3.50%, although up to quite recently the silicon was held at a minimum of 3.00%. The origin of these specifications is obscure, but it seems evident that they were written with the object of producing an iron that would possess the highest degree of machinability. As silicon was the element widely known to restrain carbide formation and promote machinability, this element was specified on the high side. The fact that silicon increases the fluidity of the molten metal and reduces the chilling rate, lent support to the assumption that high silicon was necessary for welding purposes. This use of silicon as a controlling factor for graphitization was in accordance with foundry practice at that time when the influence of total carbon was little understood and its control neglected, and the analysis for cast-iron rods became standardized at this time.

In the interim research has proved that graphitization is dependent upon both silicon and carbon and that much better control of the combined carbon is obtained by holding the total carbon within rather close limits, a variation of plus or minus 0.05% being customary. Silicon still plays its important role as the most effective graphitizing agent but the amount present is determined by the total carbon content.

The effect of silicon as a graphitizing agent varies with the total carbon content of the iron. In general, to obtain the same percentage of combined carbon a low total carbon iron requires a much higher silicon content than a high total carbon iron. In the lower part of the total carbon range, that is, at 3.00% and on down to 2.50% a content of 3.00% silicon or higher would be necessary to produce a sufficiently low combined carbon for welding purposes. In the upper part of the permissible range, around 3.35% total carbon, the minimum silicon content of 2.75% and the commonly used 3.00% plus results in a lower combined carbon than required. The combined carbon is the factor that controls the physical properties of cast iron, and in commercial practice the rods being manufactured fall in the upper total carbon range and are generally held within 3.30 to 3.40%. The broad range of total carbon permitted in the current specification and the minimum limits on the silicon content excludes the full utilization of our knowledge of the control of the total carbon content.

In order to check this supposition a cast-iron weld rod was made in which the relatively high total carbon of 3.35% was maintained, and the silicon reduced to 2.20%. Oxyacetylene weld deposits were made under the customary welding procedure and the results showed that neither the hardness nor the machinability were adversely affected. The Brinell hardness of this low silicon type of iron is approximately 228. This Brinell reading is in exactly the same range as weld deposits made with the higher 3.00% silicon weld rod.

The silicon content of a given total carbon iron is inversely proportional to the tensile strength. The high 3.00% silicon rods produce welds of approximately 20,000 psi., which is about as low a strength iron as can be produced commercially without a full anneal. On the other hand, the 2.20% silicon rod of the same total carbon content produces welds of approximately 35,000 psi., an increase of almost 75% over the cast-iron rods in common use today.

As the phosphorus in the presence of low silicon might have a tendency to embrittle this type of iron, it is kept to a maximum of 0.20%, as compared to 0.75% in the accepted high silicon iron. Phosphorus in high silicon iron rods can be increased up to approximately 1.50% and by doing so there is a noticeable increase in fluidity, and probably a slight decrease in the melting point. However, decreasing the phosphorus content of the low silicon rod did not adversely affect the fluidity, and observation of the molten weld metal indicated that if anything the fluidity was superior to the normal 3.00% silicon rod.

Later experiments showed that except for phosphorus content of around 1.00% and upward, the fluidity was governed by the surface condition of the rod. In all instances where the oxide film and impurities were removed, the fluidity of the molten metal showed a marked improvement.

From this observation it seems acceptable to conclude that lowering the silicon and phosphorus produces either a surface on the cast-iron rod that is less susceptible to oxide film formation and sand freezing, or a surface from which such films and inclusions can more readily be removed by normal cleaning processes.

Due to the fact that the tensile strength of cast-iron rods can be improved 75% by reducing the silicon and phosphorus content of a cast-iron rod of a specific total carbon analysis without adversely affecting the hardness, machinability or fluidity, it would seem that such an iron would offer a much better balance of physical properties for welding purposes. The above is predicated upon the assumption that the total carbon is the controlling factor in cast iron and that the effect of other elements must be considered in the light of the total

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† Manager, Weld Rod Division of The Chicago Hardware Foundry Company, North Chicago, Ill.

carbon present. The above experiments and observations were made on a relatively high total carbon type of iron, ranging from 3.15 to 3.40% carbon, and commonly called high test iron.

This same effect of increasing the tensile strength and fluidity without adversely affecting the hardness and machinability, can be accomplished by the use of alloys. In such an instance part of the silicon can be replaced by either nickel or copper in the established equivalents, and hardening and strengthening agents such as molybdenum, chromium, vanadium or titanium, within specific ranges can be added to produce particular properties. Combinations such as molybdenum-nickel, molybdenum-copper, copper-titanium, copper-vanadium and vanadium-titanium, have been found to result in a very fine-grained, strong, sound weld deposit; however, these combinations in the same amount have been found to be much more effective in the 2.20% silicon than in 3.00% silicon iron. Undoubtedly all the wide ranges of physical properties that are being produced by the use of alloys in iron castings can be reproduced in weld metal.

The progress in cast-iron electrodes was somewhat parallel to the oxyacetylene rod, in that early conceptions became frozen and little concentrated effort was placed on developing a cast-iron electrode.

Early experiments by the welding development men showed that cast-iron rods when coated in accordance with their concepts would not deposit gray iron welds, and the known propensity of iron to harden under rapid chill conditions lent further support to the belief that the problem had no solution, except through the use of preheating, which was in the nature of an evasion rather than a solution, and hardly offered any improvement over oxyacetylene welding.

Faced with the conclusion that a cast-iron electrode could not be developed that would avoid the necessity of preheating and be comparable to a steel electrode, their efforts were turned toward developing a substitute. There resulted from this, several electrodes which were quite satisfactory, that did much to encourage the electric welding of cast iron and which are in common use today. Monel and nickel electrodes were developed early and later improved further; steel electrodes with special coatings were found suitable for certain types of work and still later composite rods, consisting of a core and a sheath, were introduced. A few determined minds kept the original problem in sight as revealed by the literature of the 1920's and 30's, and undoubtedly some incidental thought was given to the matter by research men. There seems to have been a fairly common agreement among those few who worked on the problem, that the presence of carbon in the coating was essential and when the problem was finally solved late in 1938 this conclusion was confirmed.

The presence of graphite in the cast-iron electrode coating, although essential, will not in itself produce a commercially acceptable gray iron weld. It was found early in this development work that graphite in combination with silicon and a small quantity of slag-forming ingredients would produce a satisfactory weld with a high degree of regularity and this discovery led to the introduction of a cast-iron electrode.

Subsequent work showed that silicon was not the only element that would produce gray iron welds when used in combination with graphite. When this was revealed it seemed evident that some established metallurgical process should fit the known facts and it is now believed that the process of inoculation accounts for the results. In foundry practice the melt is at a high temperature for a sufficient length of time and is fluid enough for the graphite, ferrosilicon or other commercial compounds to inoculate the metal and provide a nucleus to start the carbon precipitating as graphite. It is these conditions of time of fluidity which are not present in the molten weld metal from cast-iron rods when coated with graphite either alone or in combination with slag-forming ingredients.

The presence of large quantities of graphite in the coating makes possible a higher temperature in the arc and molten metal, and the presence of large quantities of silicon slightly lowers the melting point with the combined result of an extremely fluid weld metal which compensates for the short-time element and permits inoculation to occur. In the case of the graphite-silicon type of coating, undoubtedly both the graphite and the silicon contribute to the inoculation as both have been used successfully in ladle inoculating.

In the case of the other elements found to be successful when used in combination with graphite it is probable that the graphite plays the major role in inoculation and that the metallic elements condition the weld metal by producing the necessary fluidity, thus permitting inoculation, by the graphite, to occur. Phosphorus has now been found to be as equally effective as silicon and in every way comparable. Titanium is by far the most effective yet found; however, it seems to be too sensitive at the fusion zone when welding certain low carbon low silicon types of iron. Copper will produce the desired characteristics but it, too, seems to be sensitive. These metals can be used alone or in combination with each other.

Of the other metals nickel seems to be more or less neutral in conditioning the metal although it can be used as an alloy. The metals, chromium, vanadium, molybdenum and zirconium exhibit the same characteristics as when used in cupola and when present in the proper quantities in the coating, and are definitely hardening and strengthening agents. Through their proper use, in combination with conditioning metals, cast-iron weld deposits possessing a tensile strength of approximately 50,000 psi. have been produced which have been completely machinable with Brinell hardness around 275.

The potency of the inoculation in reducing the chill tendencies of the weld metal is shown by the fact that weld specimens have been quenched from a bright red heat and were still readily machinable. It is further evidenced by the reduced chilling effect that elements possess when introduced through the coating. For instance, in order to condition the metal for inoculation a silicon content of from 4.50 to 7.50% in the weld metal is required. This same amount in cupola iron would produce a white iron. Phosphorus is present in from 1.50 to 3.00%, which would chill gray cupola iron. Titanium is effective up to 1.50%; whereas, over 0.15% in cupolas, shows a hardening effect. With chromium, nickel, vanadium, molybdenum, manganese and zirconium up to 1.00% can be introduced without any noticeable effect, and at 1.50% the characteristics generally attributed to these elements become evident.

Thus, as graphitization in cast-iron electrodes can be controlled, and as most of the alloys can be introduced into the weld metal, it is possible to make electrodes that will produce specific physical properties just as has been done in steel and alloy steel electrodes. Practically any base iron can be used and its properties either reproduced, modified or emphasized as desired by adjustment in the composition of the coating.

These developments in the electric welding of cast iron, and the improvements possible in oxyacetylene rods, through the application of foundry research, suggest that cast-iron welding is not fixed and stabilized but that its period of development is just starting.

THE AMERICAN WELDING SOCIETY

ACTIVITIES — RELATED EVENTS

THE PRESIDENT'S MESSAGE

At the time of the annual meeting the primary consideration of members is the wealth of technical information available through the program and the contacts of a national gathering of engineers. At no other time does the individual have as great an opportunity of benefiting from his membership in the Society.

There is another phase of the annual meeting. Whenever engineers organize with thoughts of mutual benefit, they assume certain obligations to the community and to the nation. They cannot avoid these responsibilities because they are the most competent to assume them. It is, therefore, fitting that consideration be given to the unsolved problems of welding engineering.

The most immediate problem in each community is educational. There is required not only the dissemination of current information to members of the A.W.S. but the education of design and production engineers in the limitations, practices and standards of welding, and the creation within management of that interest and good judgment essential to the application and development of the process.

These educational problems pertain largely to the sections. The requirements of war production have resulted in the establishment of new centers of welding industries, which are not served by existing sections. The Society cannot perform its duties to these new welding communities unless it enlarges its membership and sections to include them. This problem pertains to our Districts as well as to the national headquarters.

In the engineering professions there is still a question as to how new engineers shall be trained. There is little recognition in the engineering schools of welding engineering as an independent profession. Courses in welding are given but only one university gives a degree in welding engineering. Yet there is an increasing demand for engineers specialized in this field. Our schools need assistance from industrial engineers in formulating courses of training.

The training of welding operators in special schools requires attention both from the point of view of the student and of the industrial plant which will employ him. Maintenance of good standards is essential.

There still remains much work to be done in the preparation of codes, standards, recommended practices and specifications. Much desirable work remains to be organized. A greater rate of progress on work authorized is needed. The efficiency of expansion of war industries would have been greater had more standards been available.

Whether industry has a voice in the preparation of standard practices for the processing of war materiel depends upon the promptness of functioning of the technical society. It is to be hoped that the initiative for such work remains with the technical society.

The wider use of low alloy steels in welded structures and the introduction of new series of low alloy steels brings up new technical problems. Little has been done in the preparation of standards and recommended practices for welding these steels.

For resistance welding there are few standards.

During war the dissemination of technical information becomes a serious problem. There is grave danger of withholding from publication information badly needed by industry for the efficient processing and fabrication of war products. There does seem to be a realization that the enemy has spent a greater engineering and scientific effort over a long period of time than we have in the development of war products. This is no time to conceal ignorance.

These are only a few of the many problems that confront welding engineers. A wise solution of these questions will be a major contribution to the prosecution of the war.

G. F. JENKS

BY-LAW AMENDMENTS

The following By-Law Amendments and addition to the By-Laws now stand approved by letter ballot vote of the A.W.S. membership:

Article VIII, Section 1 (m)

A Committee on Awards consisting of *five* individuals each serving for a period of *five* years. The appointment shall be arranged in such a way that one member shall retire *on the adjournment of* each Annual Meeting. The member senior in respect to service shall be Chairman. It shall be the duty of this Committee to make the award and arrange for the presentation of *such medals or other awards as may be authorized by the Board of Directors.*

Article VIII, Section 1 (n)

A Committee on Permanent Funds consisting of five members, each serving for five years, *and the Treasurer of the Society, ex-officio.* The appointments shall be made in such a way that one member shall retire at each Annual Meeting. The member senior in respect to service shall be Chairman.

Funds turned over to this Committee by the Board of Directors shall be in its custody for safe-keeping, investment or reinvestment. All acts of the Committee shall require the favorable vote of at least four members of the Committee.

No disbursement shall be made from these funds except upon a favorable vote of at least two-thirds of those present at a meeting of the Board of Directors called for that purpose at which a quorum is present.

A notice of the meeting shall be sent to each member of the Board of Directors at least two weeks before the date set for the meeting. The notice shall set forth the reasons why the disbursement is proposed.

The Committee shall keep full and accurate accounts of receipts and disbursements in books belonging to the Society, and shall render a financial statement to the Board of Directors annually, or oftener if requested.

Article VI, Section 5

Addition:

Duties of District Vice-Presidents. The District Vice-President shall be the official representative of the Society in his District. He shall be responsible for the general promotion of the Society in his District and shall act as contact man between Headquarters and his District. He shall perform such other duties as specified in the By-Laws.

Renumber *present* Sections (Article VI) "5 to 7," "6 to 8."

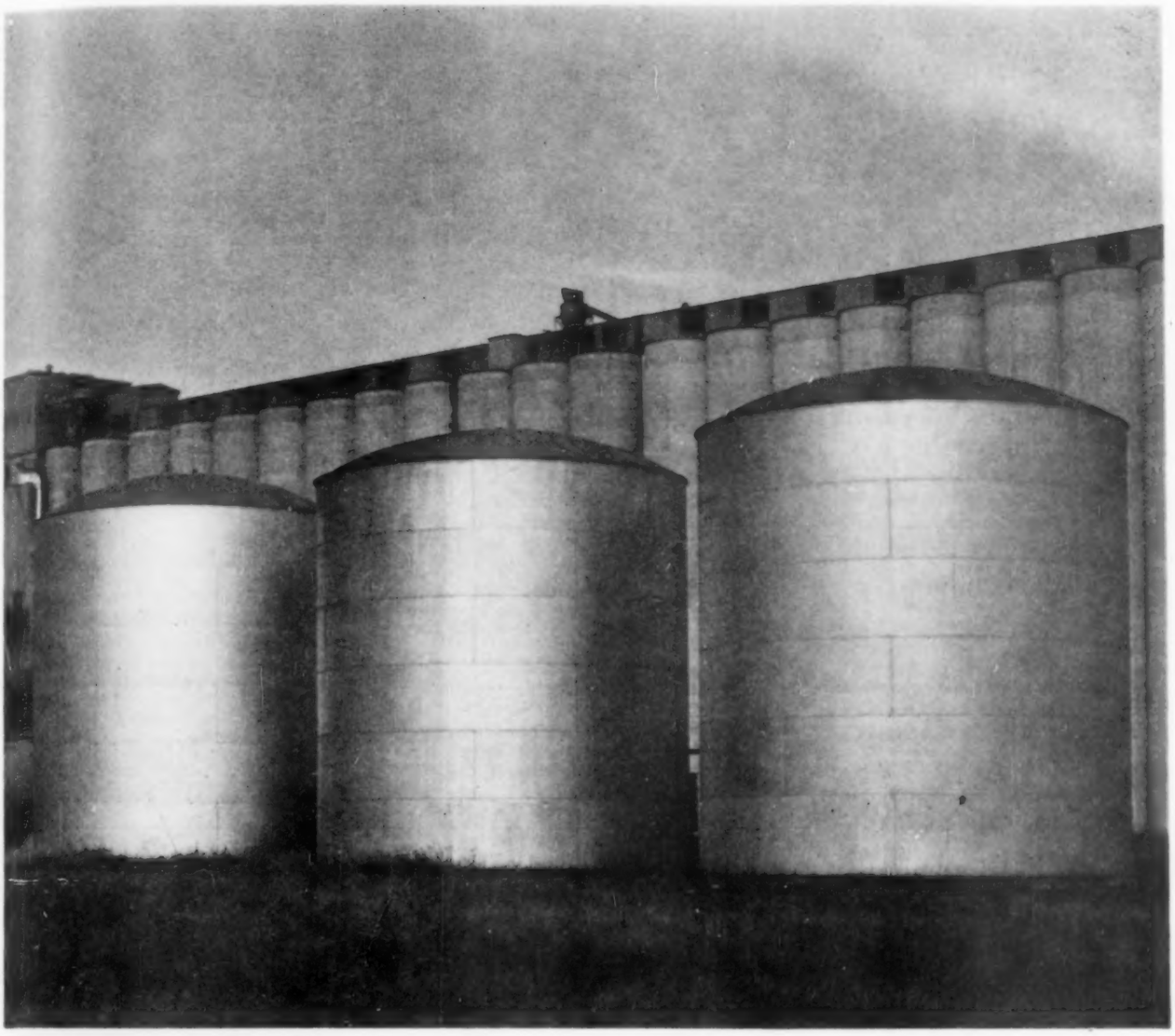
These were published in the June WELDING JOURNAL for consideration, and submitted for letter ballot vote on July 10th. September 10th marked the expiration of the 60-day period for return of ballots. The amendments were approved and will be incorporated in the By-Laws appearing in the 1942 Year Book.

MEMBERS IN ARMED SERVICE

At the May 7th meeting of the Board of Directors and Executive Committee of the AMERICAN WELDING SOCIETY, the remittance of dues of members in the armed forces was considered and the following actions taken:

In the case of members who had joined or been inducted into the armed forces and who because of this are unable to meet dues payment, upon request to the SOCIETY, the name of such member shall be continued on an "inactive" membership list for the duration of the war.

In the case of members who have joined or been inducted into the armed forces and who because of this are unable to meet dues payment, upon application to the SOCIETY, such member can obtain THE WELDING JOURNAL during this period at a nominal annual fee of $2.00.



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The first action is intended to permit a member to retain membership without interruption, but does not provide for furnishing him with THE WELDING JOURNAL or other publications of the SOCIETY during this period. The second action makes it possible for the member to continue to receive THE WELDING JOURNAL at nominal cost. These rulings do not apply to commissioned officers.

OUR PRESIDENT

Klaus L. Hansen

After serving the SOCIETY for two years as its First Vice-President, the membership duly elected as its President Klaus Lobeck Hansen, consulting engineer, Harnischfeger Corporation, Milwaukee, Wis. Mr. Hansen was born in Sandefjord, Norway, September 14, 1882, and came to the United States in 1901. He was employed by the National Stamping Works and the Western Electric Company, both at Chicago, Ill., before entering the University of Illinois where he studied electrical engineering 1903–05. After several months with the Chicago Edison Company, he was employed by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1906 and continued with the company until 1919, his last position being designing engineer on D.C. apparatus.

While in the employ of the Westinghouse Company Mr. Hansen became interested in design of arc-welding generating equipment. In 1916 and 1917 he worked on design of constant potential generators, and somewhat later developed and designed the first single-operator set marketed by the Westinghouse Company. In 1919 he went with the Mechanical Appliance Company (later the Louis Allis Company), Milwaukee, as designing engineer, later becoming chief engineer. He left the company in 1921 to engage in consulting and development work on his own patents. He invented the Hansen arc welder, and in its manufacture and sale was associated with the Northwestern Manufacturing Company, Milwaukee, from 1924 to 1932, when it was taken over by the Harnischfeger Corporation. He holds patents on various arc-welding processes and joint patents on induction motors, and has published a number of technical papers, chiefly concerned with welding. He has been a member of the American Institute of Electrical Engineers' electric welding committee 1930 to date (chairman 1932–34), was chairman of the Milwaukee Section, A.W.S., 1933–34, and chairman of the 1937 A.I.E.E. summer convention committee.

Klaus L. Hansen

Mr. Hansen has served on numerous committees of the AMERICAN WELDING SOCIETY. He was for several years Chairman of the Section Officers Conference Committee and quite active in the affairs of the Section. He was active in bringing about a revision in the returns to Sections by national headquarters. He served as Chairman of the Committee on Electric Arc Welding Equipment of the 1942 edition of the *Welding Handbook* recently issued.

The SOCIETY has secured an outstanding engineer and executive as its President.

OUR FIRST VICE-PRESIDENT

David Arnott

Mr. Arnott, who has served the AMERICAN WELDING SOCIETY as its Second Vice-President for two years, has been elevated

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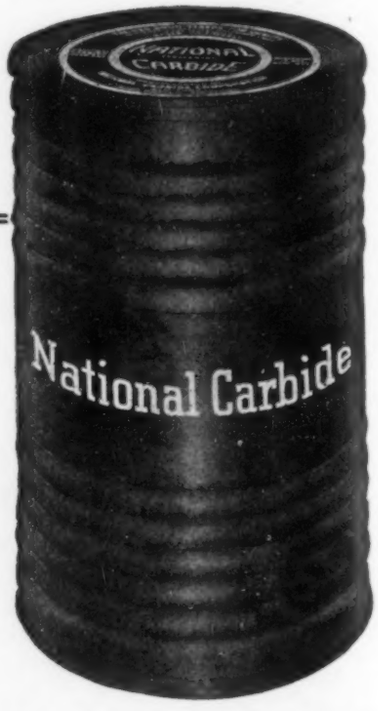

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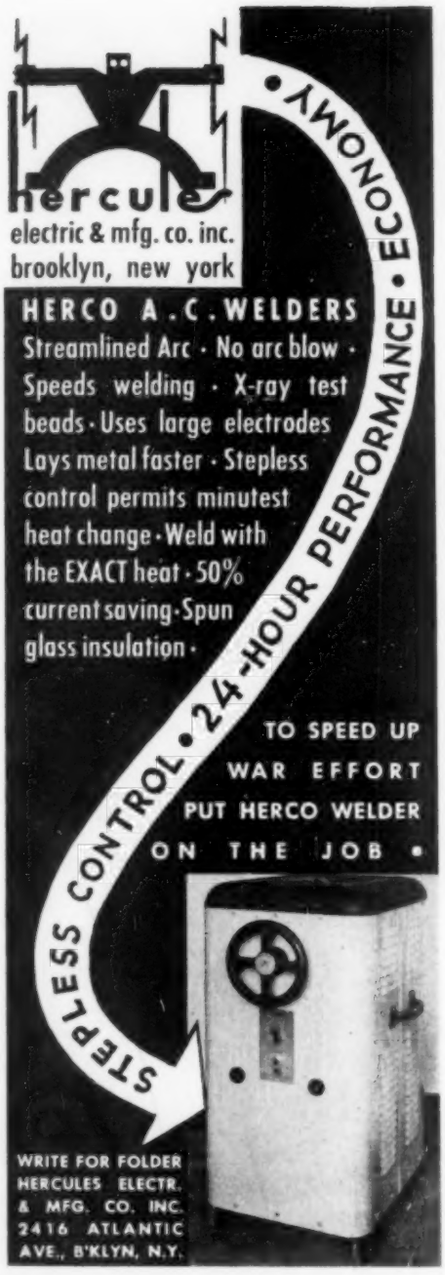
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David Arnott

to the position of First Vice-President of the SOCIETY.

Mr. Arnott has been active in the SOCIETY since its early days, particularly in its technical activities relating to ship welding. He has delivered a number of papers before the various Sections of the SOCIETY and was author of an important chapter of the first edition of *Welding Handbook*. Mr. Arnott served as Chairman of the Committee preparing the Chapter of the new 1942 edition of the *Handbook* on Ships. Mr. David Arnott has been a strong supporter of the research activities of the SOCIETY and at the present time is Chairman of the A.W.S. Committee on Welding in Marine Construction. He has also served on the Executive Committee of the SOCIETY.

Mr. Arnott was born in Glasgow, Scotland, 1878. He is a graduate of the Royal Technical College, Glasgow, and received his apprentice training in ship construction with the Fairfield Shipbuilding & Eng. Co., Ltd., Glasgow. He has served as Surveyor, British Corporation Register of Shipping and Aircraft from 1901 to 1917, at head office in Glasgow. He was also Principal Surveyor for Canada, British Corporation Register of Shipping and Aircraft, from 1917 to 1918, stationed at Toronto. Later he became Deputy Chief Surveyor, American Bureau of Shipping, from 1918 to 1925, New York. In 1925 he became Chief Surveyor of the American Bureau of Shipping, a position which he holds at the present time. To these duties were added those of Vice-President of the American Bureau of Shipping in 1938, which position he also now holds.

His technical society affiliations are quite numerous and include: Council Member, Society of Naval Architects & Marine Engineers; Member, Institution of Naval Architects; Member, British Institute of Welding; Technical Advisor to U. S. Delegation, International Safety of Life at Sea Convention 1929; U. S. Delegate to International Load Line Convention 1930. Mr. Arnott became a naturalized citizen of the U. S. A. in 1924.

The Miller Medal was awarded to Mr. Arnott last year for conspicuous contributions to the art and science of marine welding.

The Bureau of Shipping, with which Mr. Arnott has been associated for the last 23 years, has played a prominent part in the application of welding to ship construction. This application was one of gradual evolution, whereby welding at first was used in assembling parts of the ship which were not of importance structurally. In 1927 the American Bureau of Shipping made possible full classification for all-welded vessels, the first classification society in the world to do so.

OUR DIRECTORS-AT-LARGE

E. V. David

Mr. E. V. David was born in the United States but studied mechanical engineering at the Winterthur Institute of Technology, Winterthur, Switzerland, where he graduated in 1912. Returning to the United States, he was employed by Newport News Shipbuilding and Drydock Company, Newport News, Va., until 1915. He then spent two years as Inspector for U. S. Navy at Bethlehem Steel Corp.,

E. V. David

Ship Division, Quincy, Mass. Entering the U. S. Navy in 1917 as Ensign, he served on the U. S. Flagship "Pennsylvania" throughout the World War, attaining the rank of Senior Lieutenant. He resigned in 1919 and accepted a position as marine engine designer at Federal Shipbuilding Co., Kearny, N. J. He left in 1920 to go with International General Electric Co. in Buenos Aires, Argentina. Returning to the United States in 1922, he served as an Inspector for Hartford Steam Boiler Inspection and Insurance Company, New Orleans Office, until 1924. He resigned to take a position with U. S. Shipping Board, New York, as Inspector, which he held until 1927. He then became connected with N. Y. Steam Corp. as Assistant to the Chief Engineer. In 1929 he went with Air Reduction Sales Company, with which concern he now holds the position of Assistant Manager, Applied Engineering Department. He is a member of A.W.S., I.A.A. and A.S.M.E.

Mr. David has been active on numerous committees of the AMERICAN WELDING SOCIETY. He gained particular distinction through his services as Chairman of the Program Committee for a number of years and was instrumental in the development of broad technical programs for the Annual Meetings of the SOCIETY. During the

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Acme Electric Welder Company, Los Angeles, Calif.
Eisler Engineering Company, Newark, N. J.

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S-M-S Corporation, Detroit, Mich.

past two years he has served as Chairman of the Convention Committee. Mr. David is a past chairman of the New York Section of the SOCIETY. He is a member of the Finance Committee and a member of the Executive Committee.

* * *

James H. Critchett

The AMERICAN WELDING SOCIETY is honored in securing the services of Mr. James H. Critchett, Vice-President of the Electro Metallurgical Company and Vice-President and General Manager of the Union Carbide and Carbon Research Labs. Inc., as one of its Directors.

Mr. Critchett was born in Watertown, Mass., in 1886. He is a graduate of M.I.T. (1909) with the degree of S.B. in Electrochemistry.

After graduation from M.I.T., his earliest business connection was with the steel industry where he had a part in the development of the first large-scale manufacture of electric furnace steel. Following that, several years were spent in the construction industry. Since 1915 he has been with the Union Carbide and Electro Metallurgical Companies, first at their Niagara Falls plant where he took part in the development of the modern phases of the electrometallurgical industry and later at their New York office.

In addition to membership in the A.W.S. he is a member of several technical societies, such as A.S.T.M., I.A.A., A.F.A. and the Electrochemical Society, of which he is a past-president. As a member of the

James H. Critchett

War Metallurgy Committee and of the Metals and Minerals Advisory Committee of the National Academy of Sciences, he is contributing to many phases of war effort.

Since its inception, he has been a member of the executive committee of the Welding Research Committee of Engineering Foundation, chairman of the Literature Division, and chairman of the Welding of Low-Alloy Steel Committee of the Industrial Division of that organization. For some years he has acted as chairman of the Committee on Gas Filler Metal, first of the A.W.S. and later of the joint A.W.S.-A.S.T.M. Sub-Committee. A number of technical articles and papers have been contributed by him before the A.W.S., A.S.M., A.I.M.M.E., A.E.C. and others.

Mr. Critchett was Chairman of two of the committees preparing Chapters for the 1942 edition of the *Welding Handbook*.

* * *

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bringing about a better understanding between the Resistance Welder Manufacturers Association and the AMERICAN WELDING SOCIETY. Mr. Gordon joined the Kelsey Wheel Corporation in 1923. After 18 months he decided to enter the special equipment field in the design and sale of special equipment suited to the automotive industry. In 1936 he joined The Taylor-Winfield Corporation as Manager of their new fabricating plant in Detroit. On Dec. 1, 1937, he was appointed General Manager of their Warren and Detroit plants which position he still holds. Mr. Gordon is an ardent enthusiast of resistance welding and believes in the promotion of cooperative research and the intelligent application of sound engineering fundamentals to the design of resistance welding equipment. He is 40 years of age and has one daughter.

Several years ago the resistance welding industry was not well organized. Mr. Gordon was one of the prime movers in organizing and developing the work of the Resistance Welder Manufacturers Association. Through his untiring efforts cooperative arrangements have been developed with the R.W.M.A. and the individual companies thereof to the mutual advantage of both the A.W.S. and the resistance welding manufacturers. As a result of such cooperation, resistance welding is being placed on a sound scientific and engineering basis. Mr. Gordon is chairman of the A.W.S. Resistance Welding Standards Committee. He is active on other committees of the SOCIETY, including the Executive Committee and Committee on Outline of Work.

* * *

A. C. Weigel

"Al" as he is known to all of his friends was born July 13, 1887. He graduated from the University of Tennessee in 1908. He joined the Walsh & Weidner Boiler Co. and remained with them until its acquisition by Combustion Engineering Co. in 1928. He has been with the latter organization ever since.

At present he is Vice-President of this company. Mr. Weigel, in addition to being a member of the SOCIETY and its Executive Committee, is also a member of the A.S.M.E. Boiler Code Committee, Newcomen Society and other technical societies.

During the past year Mr. Weigel has served as Chairman of the Publications Committee of the SOCIETY.

"Al" Weigel possesses rare judgment and tact and is an outstanding executive. He is keenly interested in welding matters and in the SOCIETY.

A. C. Weigel

OUR DISTRICT VICE-PRESIDENTS

New York and New England—Edwards R. Fish

Mr. Edwards R. Fish, New York and New England District Vice-President, prepared for college at the St. Louis Manual Training School and was graduated from Washington University in St. Louis with the degree of Mechanical Engineering. After brief periods of employment in charge of the University Testing Laboratory and the street railway department of the General Electric Company, he became associated with the

E. R. Fish

Heine Safety Boiler. With that company he served in practically all departments gaining a wide experience in the design, manufacturing, sales and operation of boilers and pressure vessels. While in charge of the boiler shop he became interested in welding and used it to a limited extent. As a member of the A.S.M.E. Boiler Code Committee he had a large part in formulating the requirements for welded construction by which the use of welding for boilers and pressure vessels was formally recognized by the Code Committee.

Since joining the AMERICAN WELDING SOCIETY he has been active on several committees and interested in the promotion of welding in the construction of structures of all kinds.

He participated in the organization of the Connecticut Section of the SOCIETY and was its first Chairman.

He is at present Chief Engineer of the Boiler Division of the Hartford Steam Boiler Inspection and Insurance Company.

Mr. Fish is also chairman of the A.S.M.E. Boiler Code Committee and chairman of a committee that prepared the A.W.S. Code on Inspection, which was also published as a chapter of the 1942 edition of the *Welding Handbook*.

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Castolin Eutectic LOW TEMPERATURE WELDING

This new low temperature method has revolutionized welding. It binds without melting the base metal. This means high strength . . . matching color. It means less stresses . . . less warping . . . less preheating.

Try this modern welding method in your shop. The results will amaze you.

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ELECTROLOY ALLOYS for RESISTANCE WELDING ELECTRODES and DIES

Spot
Seam
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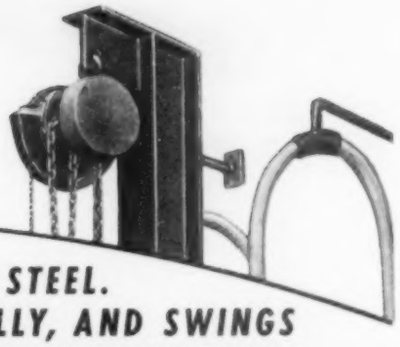
ELECTROLOY ALLOYS were developed specifically for the resistance welding industry. ELECTROLOY ALLOYS cover the full range of physical properties necessary to the manufacturers and users of resistance welding equipment.

Our engineers will be glad to make recommendations for your special electrodes. Submit samples or specifications.

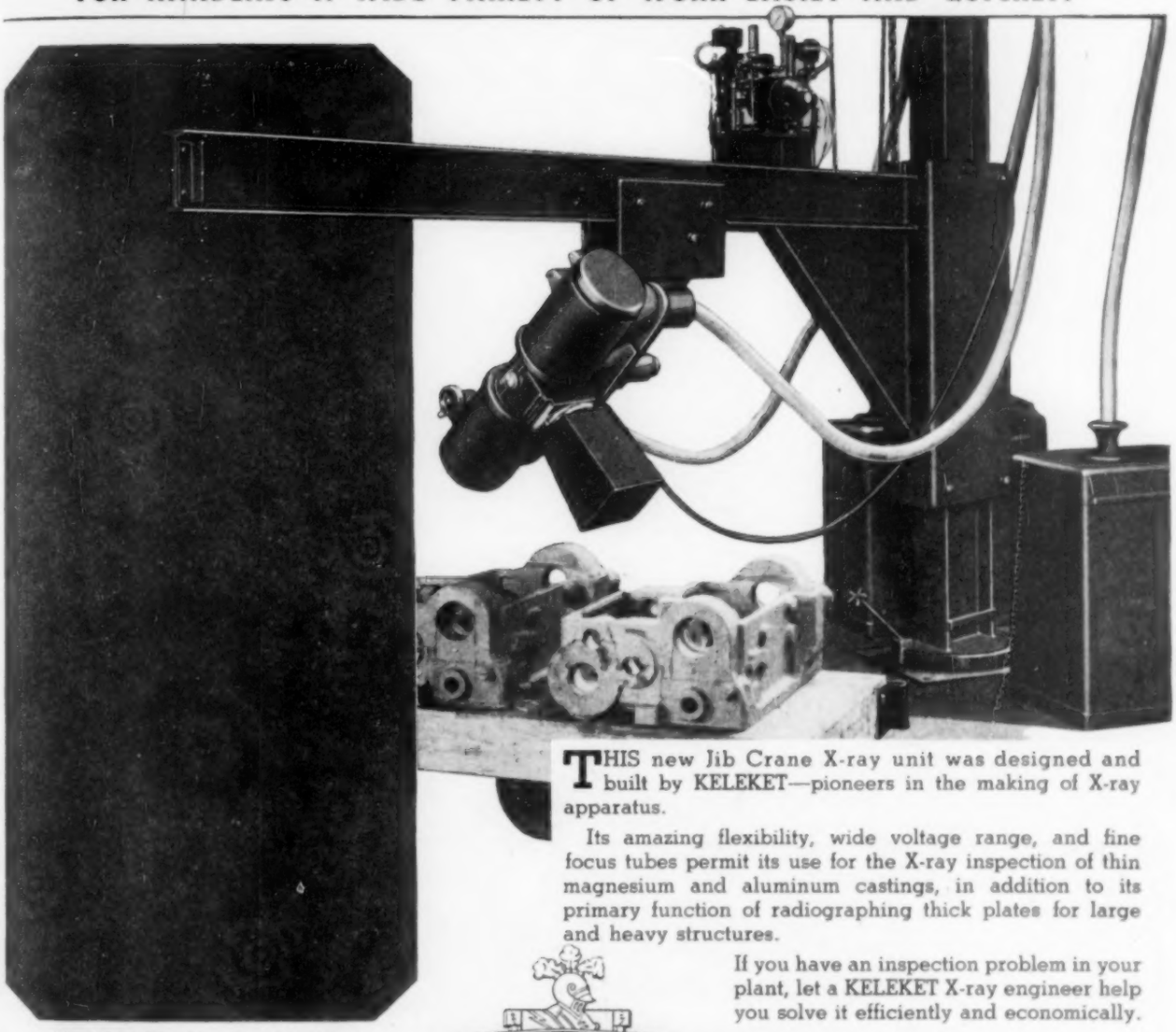
Catalog and prices available on request.

THE ELECTROLOY COMPANY, Inc. 1600 Seaview Avenue, BRIDGEPORT, Connecticut

THE LATEST X-RAY INSPECTION TOOL for HEAVY INDUSTRY



PENETRATES UP TO 3 INCHES OF STEEL. TRAVELS 6 FEET HORIZONTALLY OR VERTICALLY, AND SWINGS THROUGH A 180° ARC, COVERING A LARGE AREA OF FLOOR SPACE FOR HANDLING A WIDE VARIETY OF WORK EASILY AND QUICKLY.



THIS new Jib Crane X-ray unit was designed and built by KELEKET—pioneers in the making of X-ray apparatus.

Its amazing flexibility, wide voltage range, and fine focus tubes permit its use for the X-ray inspection of thin magnesium and aluminum castings, in addition to its primary function of radiographing thick plates for large and heavy structures.

If you have an inspection problem in your plant, let a KELEKET X-ray engineer help you solve it efficiently and economically.

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Industrial Division
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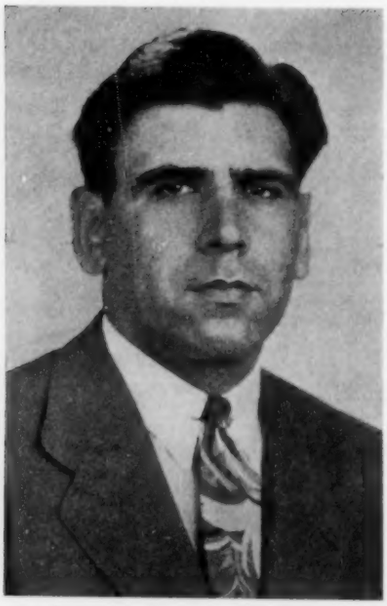
KELEKET X-RAY

JIB CRANE INDUSTRIAL UNIT

• RADIOGRAPH TAKEN WITH THIS UNIT of a 1¾" thick welded bronze plate showing defects of cracks and excessive porosity, causing the weld to be rejected.

PIONEER CREATORS OF *QUALITY* X-RAY EQUIPMENT SINCE 1900



J. H. Humberstone

Middle Eastern District—J. H. Humberstone

Mr. Humberstone graduated from the Ohio State University in 1931, with a Bachelor Degree in Metallurgical Engineering. He carried out welding investigations in obtaining this degree. He became associated with the General Electric Company as an Electrode Developmental Engineer in 1932 and was transferred to the Arcrods Corporation upon its formation in 1939.

Mr. Humberstone has been an active member of the Filler Metal Specifications Committee of the AMERICAN WELDING SOCIETY and active also in the affairs of the Maryland Section.

* * *

Pacific Coast District—P. D. McElfish

Mr. McElfish was born in Chaneysville, Bedford County, Pa. He graduated from Pennsylvania State College with degree of B.S. in Industrial Chemistry.

Mr. McElfish has had a wide and varied experience. He has served with the Metallurgical Department of the Briar Hill Steel Company, Youngstown, Ohio, 1922–23, and was a furnace helper in the Open Hearth Department of the Youngstown Sheet & Tube Co. in 1923. He was connected with the Weirton Steel Co., Weirton, W. Va., in their Metallurgical Department in 1924; later, becoming Chief Inspector, Strip Steel Department. From 1925 to 1930 he was Assistant Metallurgist, Aliquippa Works, Jones & Laughlin Steel Corporation. In 1930 he joined the Standard Oil Company of California, holding successively the titles Eastern Materials Representative, Materials Engineer, and from 1940 to date he has been Supervising Engineer in charge of inspection and material work in the Los Angeles district. He is a past-chairman of Los Angeles Section.

P. D. McElfish

* * *

Southern District—K. B. Banks

Kenneth Bartleson Banks was born in Pottstown, Pa., Nov. 3, 1891. After graduating from high school he attended Bucknell University, and, also, classes of the American Bridge Company at Gary, Ind.

Mr. Banks served for four years in the shops and drafting room of Lewis F. Shoemaker & Co., now known as Shoemaker Bridge Company. This was followed by one year in the marine repair department of the Willamette Iron and Steel Company, Portland, Ore. For six years he was connected with the American Bridge Company in their various engineering departments in Gary, Chicago and Salt Lake City. For six years he was with the Kaw Steel Construction Company, Kansas City, Kans., as Chief Engineer. He spent two years with Arthur G. McKee and Company, Cleveland, in the Engineering Department and Manager of their plant in Pulaski, Va.

K. B. Banks

For the past twelve years Mr. Banks has been connected with Black, Sivalls & Bryson, Inc., Oklahoma City, as assistant to the Chief Engineer and in charge of estimating and pricing.

Mr. Banks has been Secretary of the Oklahoma City Section for the first two years of its activity and Chairman of the Section for the next two years. He served for one year as Chairman of the local Program Committee.

He is a registered Professional Engineer in Oklahoma; member of Oklahoma Society of Professional Engineers and member of Engineers' Club, Oklahoma City.

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"

Ask for Them ***Unequalled for Quality***

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.

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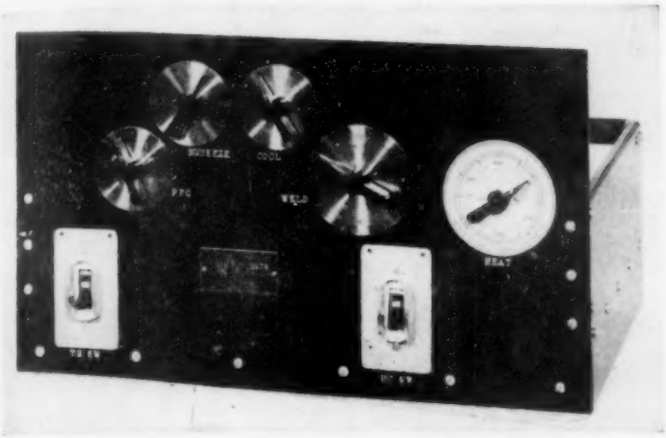
THREE A.C. SPOT WELDING CONTROLS for BETTER TOOLS OF WAR.



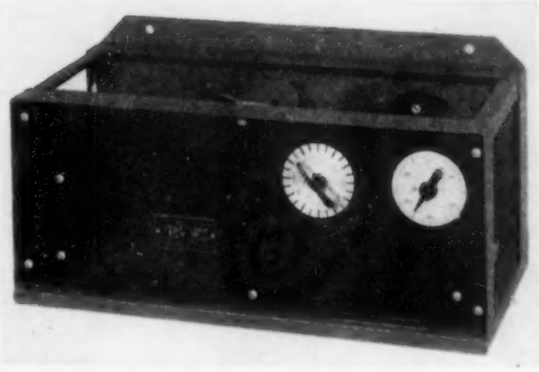
FOR ALCLAD SPOT WELDING

USE **TRI-TROL**—THE COMPLETE

WELD CONTROL and SEQUENCE PANEL, Using the Exclusive HY-LO Weld Current Control. High In-rush for ½ or 1 Cycle, to Melt the Metal and Form a Nugget, followed Immediately, without Interruption, by a Low, or Tempering Heat, that Prevents Rapid Contraction and Cracking—that Prevents Crystallization—Brittleness. Dial Control to Regulate Penetration—Other Dials for Squeeze and Hold Time. Here is a Compact Unit, enclosed in a Steel, Shelf or Wall Cabinet, that Controls the Entire Welding Cycle.

DUO-TROL (at right) for Precision Alloy Welding

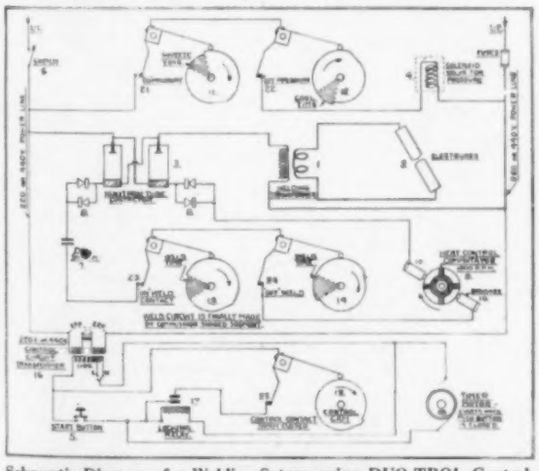
Stainless Steel and other High Tensile Alloys require very definite Heat and Time settings, if they are to pass Rigid Government Inspection. DUO-TROL provides this fine means of selecting the exact setting. Two dials —one for Heat—the other Time, yield 1,000 combinations, any of which can be selected while welding proceeds.



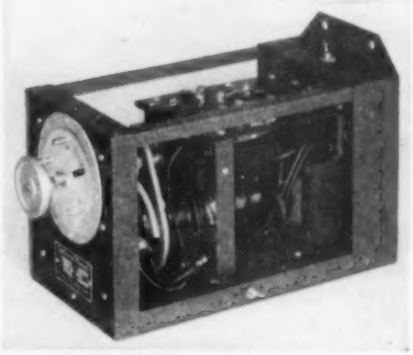
It can be attached to any Welding Machine, equipped with Air to supply Electrode Pressure — and an Ignitron Tube Contactor.

Flexibility permits its use in Welding the thinnest Alclad sheet, or metal as heavy as .062″, having a total thickness of 1/8″. It is Economical in cost, with Upkeep expense very low, while deliveries can be made promptly.

If your welding transformer had 100 primary taps, and you could select any Heat by pushing a button, you might not need DUO-TROL.
DUO-TROL Provides JUST THAT COMBINATION, and does it with any Standard Welder.
DUO-TROL is a combined Weld-Timer, Heat Control, and Sequence Panel for Electrode Pressure.
It can be attached to any Standard Air Operated Welding Machine. The schematic diagram (below at left) illustrates the simple, fool-proof circuit arrangement. Thousands of National Timers have been serving the Welding Industry, for years before the war.



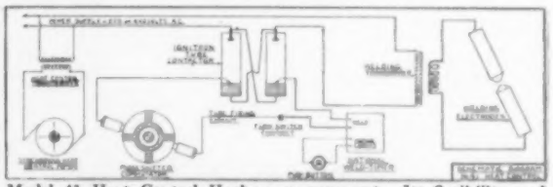
Schematic Diagram of a Welding Set-up, using DUO-TROL Control. TRI-TROL is similar, except for addition of HY-LO Heat.



NATIONAL MODEL 41 WELD HEAT CONTROL UNIT

This may be likened to a current valve, inserted in the Tube Contactor firing circuit. May be used with any ordinary Timer, Mechanical, Non-synchronous, Dashpot, and most of the Electronic types. It will regulate Weld Heat, from full transformer capacity, down to zero, in 45 gradual steps.

Easy to Install. Can be used on the smallest bench welder, or a 500 KVA Unit.



Model 41 Heat Control Hook-up arrangement. Its flexibility and quick setting, Increases Speed and Improves Work.

NATIONAL TIME & SIGNAL CORPORATION
600 E. MILWAUKEE AVENUE DETROIT, MICHIGAN

OTHER OFFICERS

Brief biographical sketches of our Second Vice-President, Isaac Harter, Vice-President of the Babcock & Wilcox Co., and the Middle Western District Vice-President, John D. Tebben, Sales Mgr., Metallurgical Div., P. R. Mallory & Co. Inc., were received too late to include in this issue. They will be published in the November number.

NEW AMPCO-TRODE 10 BULLETIN

Ampco Metal, Inc., Milwaukee, Wisc., have just released a new 6-page bulletin, letterhead size, describing in detail Ampco-Trode 10, an all-purpose, coated bronze electrode.

The new bulletin contains physical properties, chemical composition and procedures for various types of welding, using the new electrode. One of the major applications for Ampco-Trode 10 will be the metallic arc welding of cast manganese bronze, Muntz metal, and brass. Detailed instructions are given for using Ampco-Trode 10 on these or similar metals. The bulletin is illustrated by a number of diagrams showing methods of welding, deep groove preparation, building up metal on vertical surfaces, weaving sequence, and method of depositing beads.

The bulletin is issued as a supplement to the *Ampco-Trode Weldrod Bulletin*, and a copy will be sent to welding engineers on request.

TECHNICAL PUBLICITY MEN WANTED

The U. S. Civil Service Commission is anticipating an early need for men with first class experience in editing, writing and publicity plus a knowledge of the iron and steel industry, engineering machinery, aviation, radio or allied fields. Appointees will write and edit technical articles or popularize such material for the general public. Salaries range from $2300 to $4600 per year. Application Form 57 can be used in making application for these positions.

NEW CAREER OPPORTUNITIES IN THE BUILDING INDUSTRY

A brochure on the above subject was published by the Johns-Manville Sales Corporation of 22 East 40th Street, New York, N. Y. The booklet is the culmination of two years' work and contains a detailed description of the movement and its significance. It is especially designed for high school graduates planning to enter college. Copies of this booklet may be obtained on request.

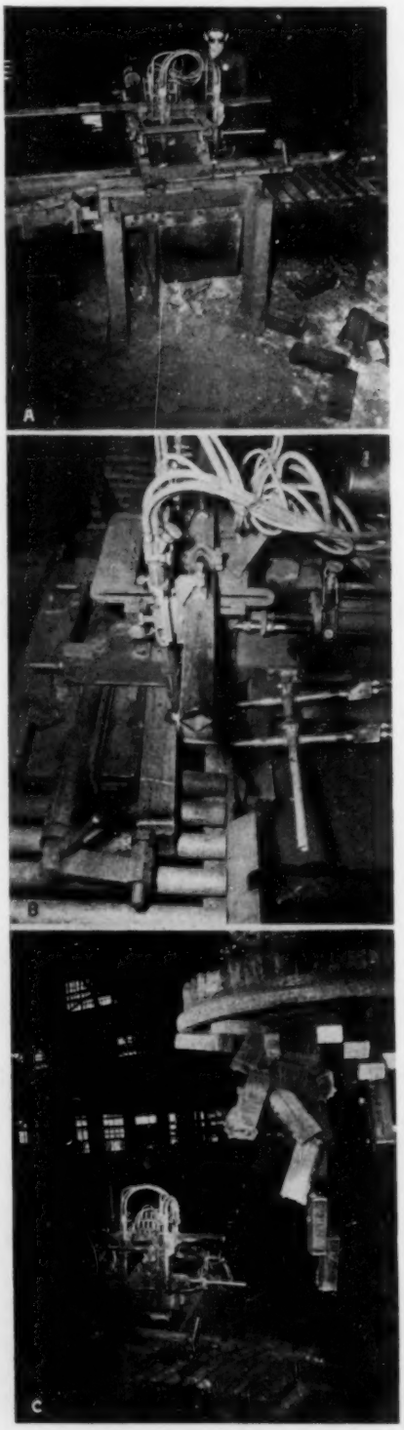
EUTECTIC WELDING ALLOYS, INC., PAMPHLET

This Company has just had published an extensive publication regarding the new Castolin Eutectic Low Temperature Welding Process. It is entirely devoted to war effort, either in the production or salvaging of machinery and tools.

This new data book has been written in such a way that it gives real information of practical value and can be used as a guide for welding problems of all kinds as they occur today. Numerous illustrations show the practical applications for the various Castolin Eutectic Alloys.

STEEL BARS BEGIN TRANSFORMATION INTO TANK LINES

This oxyacetylene cutting machine is cutting alloy steel bars into 14-in. lengths which will be forged into tractor driving links for army tanks. Bars are fed into the machine on rollers and quickly positioned for cutting by guiding stops. Two blanks are cut simultaneously by this machine, all operations of which are controlled by one operator at a control table located behind the cutting mechanism. Photo B shows a close-up of one of the cuts being made. In Photo C a load of cut blanks is being removed to the forging machines by an electromagnet conveyor.



Photos courtesy Linde Air Products Co.

ARC-WELDED TRACTOR TIRE ADAPTERS HELP MEET SHORTAGE OF RUBBER

Because of the acute rubber shortage, arc welding is being used today to give steel treads to implements designed for rubber tires, such as farm tractors, trailers and other mobile equipment.

Using welding equipment according to The Lincoln Electric Company of Cleveland, the Airlite Manufacturing Company of Emporium, Pennsylvania, has developed welded adapters for changing the rims and treads to steel. The Airlite Company has reversed the trend toward rubber tires, during which many old tractors were adapted to rubber by cutting off the old steel rims and welding on rims to take the tires.

Of particular advantage to owners of Fordson tractors, there are thousands of discarded Fordson wheels which have not been used in war work and are available throughout the country.

To adapt these discarded wheels to a tractor, the Airlite Company removes the spokes and hubs and, by arc welding, fastens adapters inside the rim faces. They may be placed very easily onto rims built for tires.

When employed as auxiliary wheels, the reconstructed Fordson wheels are fastened onto the regular tractor wheels by means of wheel mounts, which are attached near the hubs. These auxiliary wheels increase the traction area of the regular wheels, and if the regular wheels carry rubber tires, the load on the tires is lightened and the wear is diminished.

OBITUARIES

Gustav E. Harcke

Mr. Gustav E. Harcke died on August 2, 1942, in Oakville, Conn. He was born on August 12, 1878, in Waterbury, Conn.

He joined the Davis-Bournonville Company in June 1916, becoming associated with Air Reduction when this company acquired the business of Davis-Bournonville.

For many years he was active conducting Liquid Air demonstrations for this company, acquiring an enviable reputation as a lecturer and forming a host of friends throughout the country.

In recent years, Mr. Harcke devoted his services to building up the engineering and data files of Airco's general library.

* * *

Harry T. Thompson

Harry T. Thompson, District Manager of the Metal & Thermit Corporation, died

New PAGE ELECTRODE FOR ARMOR WELDING HELPS GET TANKS INTO ACTION!

A new electrode for welding armor was developed exclusively by **PAGE** *to cooperate with the change-over to welded tank production. It met all ballistic tests on plates submitted to the Army Ordnance Department by the tank manufacturers—and then went into action, having a real part in the great records that since have been set on welded tank production lines.*

It is worthwhile to note that, in spite of the pressure for speed, tank welders have been well schooled in technique that wastes no electrode—gets maximum strength with the use of no unnecessary metal in the weld—uses every electrode right down to the holder. All users of welding rod would do well to insist on their men observing such economy today.

PAGE WELDING ELECTRODES

PAGE STEEL AND WIRE DIVISION
Monessen, Pa., Atlanta, Chicago, New York, Pittsburgh, San Francisco
AMERICAN CHAIN & CABLE COMPANY, INC.
BRIDGEPORT, CONNECTICUT

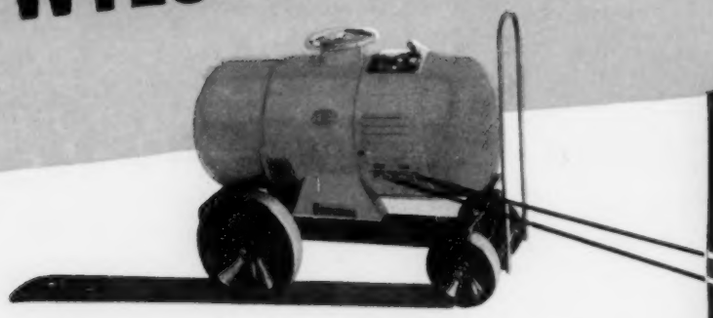
In Business for Your Safety

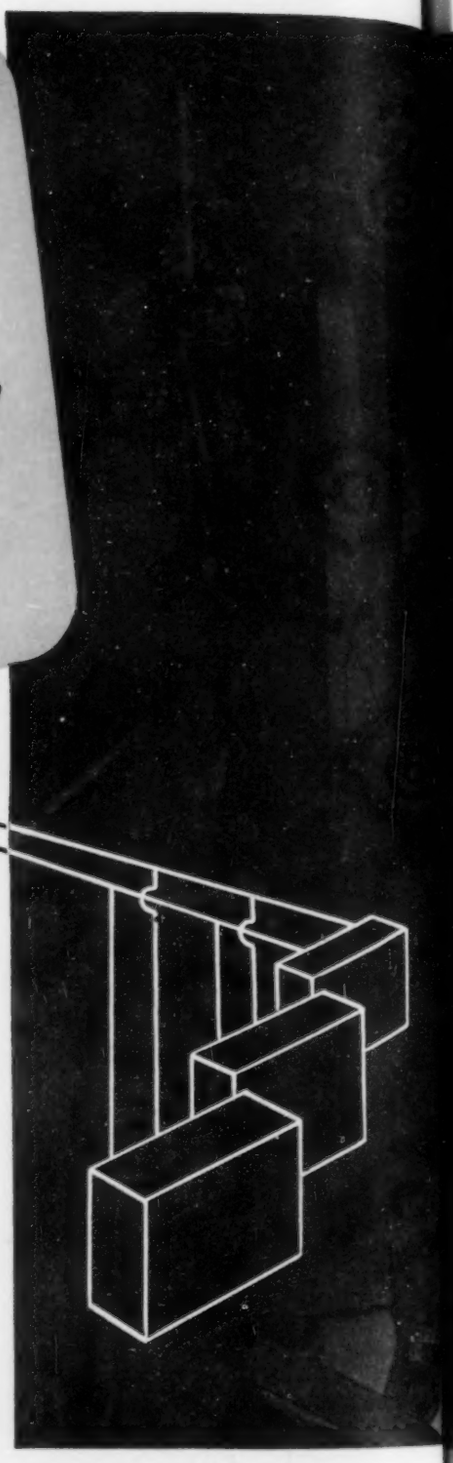
Photo by U. S. Army Signal Corps

FOR FAST, UNINTERRUPTED PRODUCTION

. . . weld with a

WILSON "HORNET"





. . . AND NOW COMING OFF THE PRODUCTION LINE THE "HONEY BEE" ARC CONTROL STATION

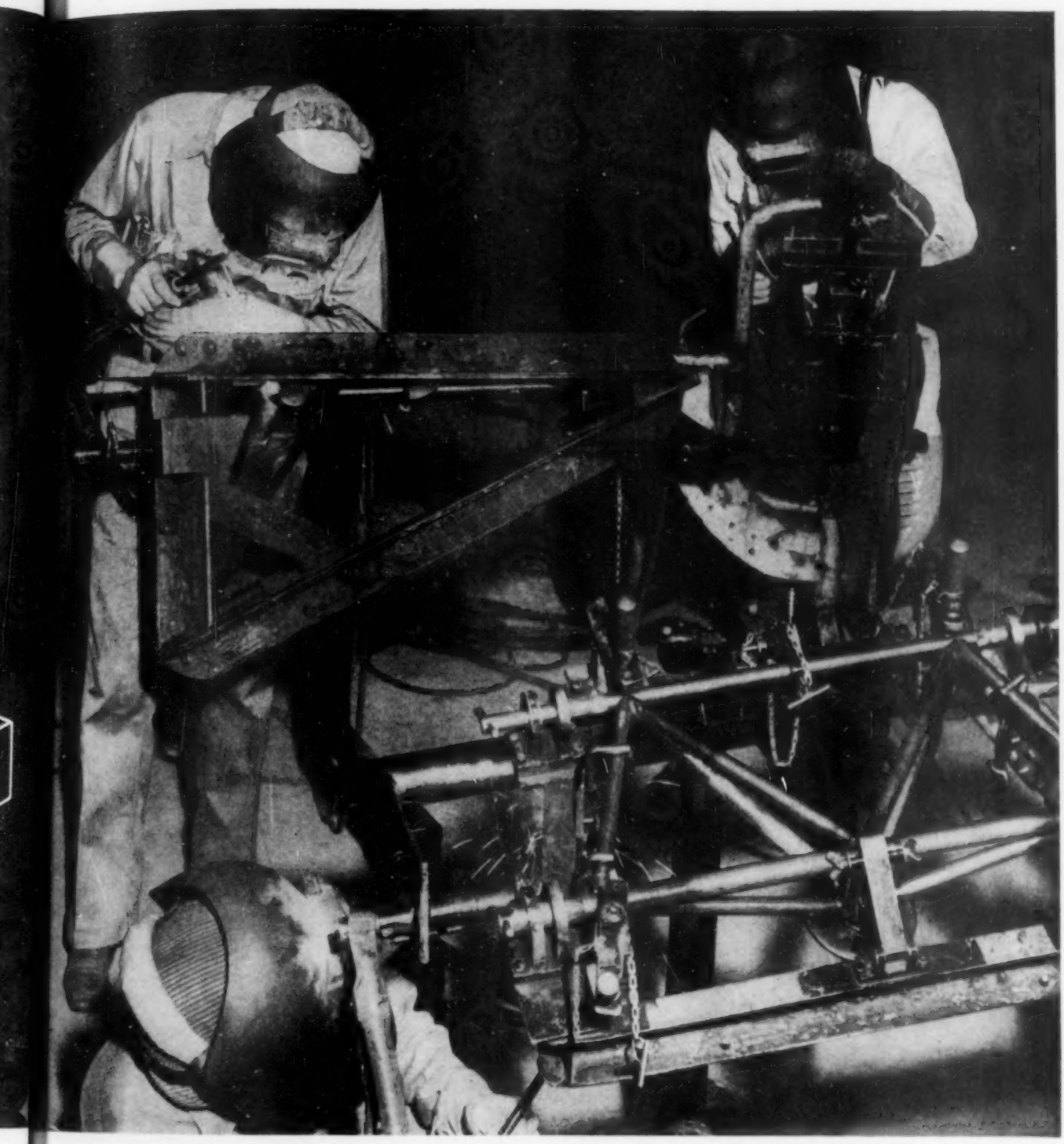
Specially developed for welding light gauge metal in the aircraft industry. It's three outstanding advantages:

1. More arcs per machine.
2. Gradual current reduction for remote crater control.
3. Remote control of all operations.

Do not fail to get complete information. Write to Wilson Welder and Metals Co., Inc., 60 E. 42 St., New York, N. Y.

WILSON WELDER AND METALS

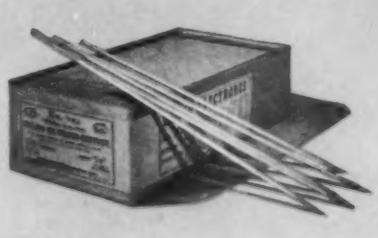
General Offices: 60 East 42nd Street, New York, N. Y.



CO., INC.

FOR ALL-POSITION WELDING OF THIN METAL AND LIGHT SECTIONS

Ideal for the aircraft industry is Wilson 520. With it, a smooth welding bead invariably results. Has excellent operating characteristics when used for a.c. or d.c. welding. Spatter loss is exceedingly low.



at his home in Mt. Lebanon, Pa., on Wednesday, August 19th, at the age of 53.

Born in Chattanooga, Tenn., Mr. Thompson attended the McCallie School of Chattanooga and was graduated from Georgia Institute of Technology in the class of 1912. During World War I he served in France as a Captain in the Field Artillery. After returning to civilian life, he became associated with the Differential Steel Car Company, Findlay, Ohio, and was later made a vice-president and director of the company, an association which continued until his death. In 1931, he joined the sales organization of the Metal & Thermit Corporation. Shortly thereafter, he was appointed District Manager and placed in charge of the corporation's Pittsburgh branch, which serves the Central Atlantic and Southeastern states.

Besides being a member of the American Legion and Phi Delta Theta fraternity, Mr. Thompson belonged to the St. Clair Country Club and the AMERICAN WELDING SOCIETY.

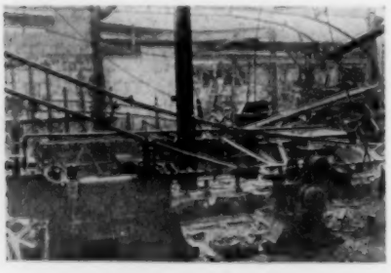
* * *

Paul R. Garrison

Paul R. Garrison, a member of the AMERICAN WELDING SOCIETY, and resident of Ottawa, Kan., died July 11th, at the age of 47. Mr. Garrison suffered a stroke of paralysis and never regained consciousness. Mr. Garrison was a machinist and owner of the Garrison Welding Service. He was an active civic worker and generally known as an all-around good fellow. For a number of years he served as a volunteer member of the city fire department.

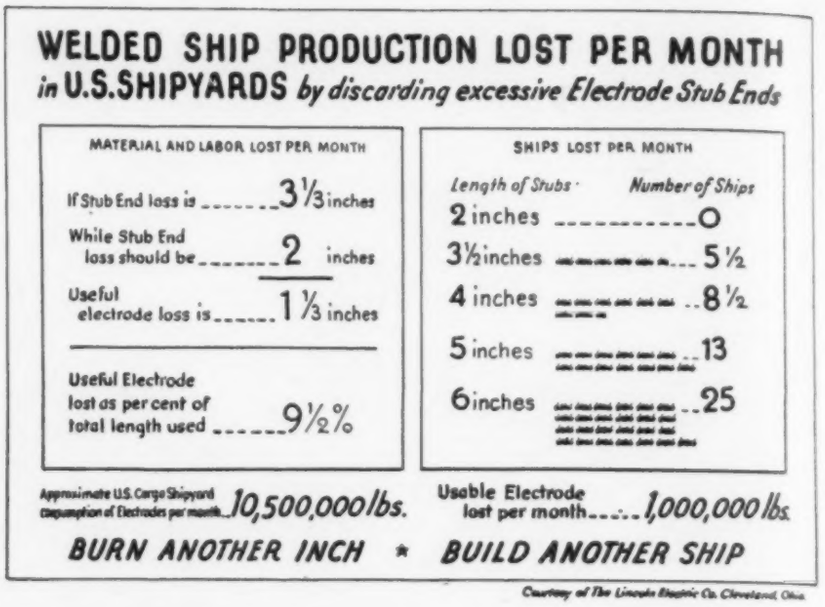
"WHITEY" MAURATH FIRE

Our member, "Whitey" Maurath, recently had the misfortune to see fire destroy Maurath, Inc., Wire Mill, part of the million dollar fire loss that swept vital war industrial plants. The Maurath plant were producers of welding rods in fabricating armor plate, and "Whitey" said his loss would be estimated at nearly $125,000. Even though insurance covered the physical property, valuable wire-drawing equipment that would take months to replace even if the equipment can be obtained was destroyed.



The fire will hold up the development of a low-alloy rod for welding armor plate.

You can't stop "Whitey," however, as he has signed an agreement for a parcel of land to put up a wire mill.


WELDED SHIP PRODUCTION LOST PER MONTH
in U.S. SHIPYARDS by discarding excessive Electrode Stub Ends
MATERIAL AND LABOR LOST PER MONTH
If Stub End loss is 3 1/3 inches
While Stub End loss should be 2 inches
Useful electrode loss is 1 1/3 inches
Useful Electrode lost as per cent of total length used 9 1/2 %
SHIPS LOST PER MONTH
Length of Stubs
Number of Ships
2 inches 0
3 1/2 inches 5 1/2
4 inches 8 1/2
5 inches 13
6 inches 25
Approximate U.S. Cargo Shipyard Consumption of Electrodes per month 10,500,000 lbs.
Usable Electrode lost per month 1,000,000 lbs.
BURN ANOTHER INCH * BUILD ANOTHER SHIP

Courtesy of The Lincoln Electric Co. Cleveland, Ohio

BURN ANOTHER INCH MORE WELDING ELECTRODE AND BUILD ANOTHER U. S. CARGO SHIP

So vital is arc welding to America's tremendous shipbuilding program that failure to use the last available four inches of a welding electrode stub would mean a loss of 25 ships a month.

Although every 14-in. electrode can be burned down to a 2-in. or less stub, workmen sometimes throw away 3 1/3 in. and some even discard as much as 6 in.

The use of merely another 1 1/3 in. on the average stub would be sufficient to add another 5 1/2 boats to the nearly 60 cargo vessels of arc-welded construction the United States is now turning out each month.

These estimates were made by A. F. Davis, Vice-President of The Lincoln Electric Company of Cleveland.

"Construction of one arc-welded cargo boat now requires the use of approximately 175,000 lb. of electrodes," Davis explained. "If you multiply that by 60, an approximation of the number of vessels of arc-welded construction coming off the ways each month, you arrive at a huge figure of 10,500,000 lb. In other words, every inch of welding electrode is vital to the shipbuilding program.

"Each original electrode is 14 in. long, and if the average welder uses only 10 2/3 in., the remaining 3 1/3 in. is thrown away as unusable.

"But we have found that he can very well use another 1 1/3 in.—enough to do all the welded construction on 5 1/2 vessels.

"By the same estimates, if he discards a 6-in. stub, he is throwing away enough electrode material to weld 25 vessels.

"Therefore, it cannot be overemphasized that every workman should use 12 in. of every 14-in. electrode that comes into his hands.

"An easy slogan for him to remember would be 'Burn Another Inch and Build Another Ship.'

"The control of stub-end losses, which are part of the cost of an electrode, is also an effective means of cost reduction, easily accomplished.

"The cost per pound of the weld metal that is deposited goes up sharply in proportion to the length of the stub end that is discarded. Thus, if 14-in. electrodes are burned to 2-in. stubs, the cost of the deposited metal is $0.967 a pound; but if 14-in. electrodes are burned to 4-in. stubs the cost of the deposited metal goes up $1.03. When 6-in. stubs are left, the cost is $1.089 and when 8-in. stubs remain the cost is $1.206 per pound.

"Labor cost per pound of electrode deposited increases with increased stub-end losses, because of a greater number of interruptions for changing electrodes and a lower operating factor. On the average, the labor cost increases 3% for each two inches above the standard 2-in. stub end loss.

"Burning down the 14-in. electrodes to stubs six inches long, the workman must make 12 electrode changes per pound of electrode material. If he burns them to 5 in., he has to make 11 changes; to 4 in., 10 changes; to 3 1/3 in., 9 changes; and to 2 in., 8 changes. Recent surveys indicate that one change requires an average of 21.6 seconds when the welder does his own cleaning of deposited bead."

AMPCO ISSUES NEW AIRCRAFT BULLETIN

How Aircraft Designing Engineers Use Ampco Metal is an 8-page, letterhead-size bulletin, being distributed by Ampco Metal, Inc., Milwaukee, Wis., producer of Ampco Metal and other bronze alloys.

The booklet describes pictorially the use of Ampco Metal by the aircraft industry. Printed in two colors, it is well illustrated with photographs of a wide variety of aircraft and equipment.

Coiling ⅓ of a mile of Inconel tubing

An integral part of fat splitting units employing the Eisenlohr Process are the three coils shown on this page. They are designed for a working pressure of 3,500 p.s.i. at 600° F.

About ⅓ of a mile of ½ in. I.P.S. Inconel tubing was required for the three coils, which are about 6½ ft. high.

This type of coil, frequently with manifolds, is made for heating or cooling the contents of vessels in chemical plants. Annealed pipe or tubing should be employed, rather than "as drawn," in order to facilitate shaping and coiling. Made in small diameters up to 5 in. of relatively thin-wall tubing, they are joined by oxy-acetylene welding.

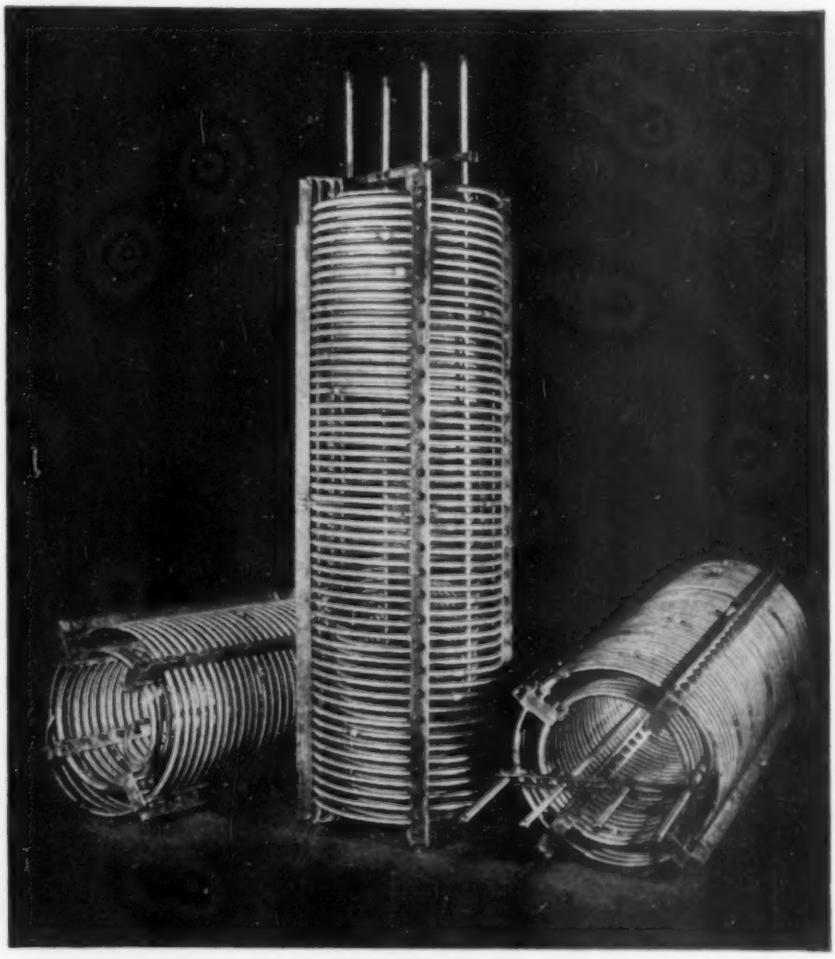
Welding wire employed is about the same diameter as wall thickness of tube. In this case No. 42 Inconel gas welding rod was used, with Inconel gas welding flux. The latter, mixed with water to a thin cream, is painted on the inside and outside of tube ends and welding rod. Butt joints are recommended for these and other piping systems.

In welding, the oxy-acetylene flame should be soft and very slightly reducing. Arc may be weaved across the joint if desired.

Neat welds that are strong, ductile, sound and resistant to corrosion result from this procedure.

For further information write for Bulletin T-17, "Fabrication of Monel, Nickel and Inconel Seamless Tubing." Address:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 WALL STREET NEW YORK, N. Y.



APPLICATION OF INCO WELDING MATERIALS

MONEL

No. 40—Monel Gas Welding Wire
For Oxy-acetylene welding of Monel. Used with Monel Gas Welding Flux.

No. 130X—Monel Metal Arc Welding Rod
For metal arc welding of Monel, Monel to steel, Nickel to steel, and Monel side of Monel-Clad Steel.

NICKEL

No. 41—Nickel Gas Welding Wire
For Oxy-acetylene welding of Pure Nickel. No flux used.

No. 131—Nickel Metal Arc Welding Rod
For metal arc welding of Pure Nickel.

INCONEL

No. 42—Inconel Gas Welding Wire
For Oxy-acetylene welding of Inconel. Used with Inconel Gas Welding Flux.

No. 132—Inconel Metal Arc Welding Rod
For metal arc welding of Inconel and Inconel side of Inconel-Clad-Steel.

NICKEL-CLAD STEEL PLATE

No. 135—Nickel Metal Arc Welding Rod
For metal arc welding of Nickel side only.

★ ★ **INCO NICKEL ALLOYS** ★ ★

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • NICKEL • "Z" NICKEL

Sheet...Strip...Rod...Tubing...Wire...Castings

it's ARCOS CHROMANG FOR VICTORY WELDS!

PURCHASING AGENTS

Arcos batting average on deliveries is high. We are in a position to meet our shipping promises because of vastly increased production facilities to meet the new demand for special stainless electrodes for war work. Arcos production is almost 100% on stainless electrodes. Its facilities cannot be diverted from stainless by larger tonnage allocation orders for steel electrodes. The Arcos plant has been running for many months on a 24-hour day, seven-day-a-week schedule. Leading plants are using Chromang in large quantities, and their reports show operator speed, a high quality deposited weld metal, and superior ballistic qualities. You can't go wrong by specifying Arcos Chromang—the electrode that has been especially developed by Arcos for armor welding.

For more detailed information, contact your nearest distributor, listed below, or write direct to the Arcos plant in Philadelphia.

CHROMANG *meets every requirement!*

WELDING SUPT'S AND FOREMEN

Chromang electrodes are easy for the operator to use because they are an all position electrode. Even for welding downhand, the all position characteristic is an advantage and this quality is obtained with no sacrifice in speed. The superior quality of Chromang is due to the fact that the important modifying element is in the core wire—not in the coating. The coating of Chromang electrodes is uniform, giving a steady, well directed arc stream.

Chromang electrodes are dependable—when used on air hardenable steels with the correct current values, they do not give cracked welds—weld shows no porosity under X-ray—no chipping out for rewelding.

Arcos electrodes are put up in a moisture-proof package which withstands all ordinary exposure. Damp electrodes are not a problem with Chromang.

BUFFALO, N. Y.—*Root, Neal & Co.* • BORGER, TEXAS—*Hart Industrial Supply Co.* • **BOSTON, MASS. (Belmont)**—*H. Boker & Co., Inc.*; *W. E. Fluke* • CHICAGO, ILL.—*Machinery & Welder Corp.* • **CINCINNATI, OHIO**—*Williams & Co., Inc.* • CLEVELAND, OHIO—*Williams & Co., Inc.* • **COLUMBUS, OHIO**—*Williams & Co., Inc.* • DETROIT, MICH.—*C. E. Phillips & Co., Inc.* • **ERIE, PA.**—*Boyd Welding Co.* FRESNO, CALIF.—*Victor Equipment Co.* • **FT. WAYNE, IND.**—*Wayne Welding Supply Co., Inc.* • HONOLULU, HAWAII—*Hawaiian Gas Products, Ltd.* • **HOUSTON, TEXAS**—*Champion Rivet Co. of Texas* • KANSAS CITY, MO.—*Welders Supply & Repair Co*

PRODUCTION MEN

WELDERS

METALLURGISTS

Chromang electrodes have the same high deposition rate characteristic of all Arcos electrodes. Every man-hour of work will give the maximum pounds of quality weld metal correctly deposited. Our customers are passing ballistic tests with consistently high scores—a proof of the uniform quality of Chromang welds. Chromang meets the requirements of all Services. Chromang is regularly produced in all the sizes from 1/8″ to 5/16″ in diameter. It can be supplied on special order in 3/8″ diameter. All diameters are 14″ long, end grip, except 5/16″ which is 18″, end grip. Stub ends are extremely short, permitting maximum use of the electrode and minimum loss of valuable electrode material. Keep your stub ends short, your production high, and your cost low by using Arcos Chromang.

Try Chromang and compare. The best test is right on your own production line.

Chromang is the welder's electrode. You don't have to fight a wild arc when you use Chromang. Slag does not interfere—weld metal washes well up on the sides. 3/16″ diameter electrodes can be used easily in the vertical position.

For months before Chromang was announced, Arcos practical welding men tested and retested until the most desirable welding characteristics were obtained. The result—front line production welders are using Chromang for welding armor.

The analysis of the Chromang weld deposit is carefully controlled to meet the important specifications for this type of weld metal. Arcos controls its products, from melting to final electrode processing, assuring uniformity from lot to lot. In fact, many users find the uniformity is so high that they no longer spot check different shipments of Chromang.

Chromang coatings are not overloaded with ferro-alloys, the essential alloy elements being present in the core wire. This assures uniformity of chemistry of the weld metal and it also gives better arc characteristics.

Chromang welds show clean X-ray pictures. It is not necessary to chip out and reweld a portion of the joint to obtain a sound weld.

The Arcos laboratory and research staff have worked unceasingly to bring Chromang to its high degree of excellence. Interested metallurgists and other officials may, upon request, inspect test data.

FOR BETTER WELDS — FASTER!

it's ARCOS for stainless electrodes

STAINLESS AND ALLOY ELECTRODES IN OVER 30 GRADES

ARCOS CORPORATION

401 NORTH BROAD ST., PHILADELPHIA, PA.

KINGSPORT, TENN.— *Slip-Not Belting Corp.* • LOS ANGELES, CALIF.—*Victor Equipment Co.* • MILWAUKEE, WIS.— *Machinery & Welder Corp.* • MOLINE, ILL.—*Machinery & Welder Corp.* • NEW YORK, N. Y.— *H. Boker & Co., Inc.* • OKLAHOMA CITY, OKLA.—*Hart Industrial Supply Co.* • PAMPA, TEXAS— *Hart Industrial Supply Co.* • PITTSBURGH, PA.—*Williams & Co., Inc.* • PORTLAND, OREGON— *Industrial Specialties Co.* • ROCHESTER, N. Y.—*Welding Supply Co.* • SAN FRANCISCO, CALIF.— *Victor Equipment Co.* SEATTLE, WASH.—*H. A. Cheever Co.* • ST. LOUIS, MO.— *Machinery & Welder Corp.* • SYRACUSE, N. Y.—*Welding Supply Co.*

Copies of the new bulletin will be sent to interested engineers.

FIRST WELD STARTS TEXAS-ILLINOIS PIPE-LINE

The first weld on the important 550-mile pipe-line from Longview, Tex., to Norris City, Ill., was made at noon, August 3rd, by Williams Brothers Corporation, first of the seven contractors to begin construction.

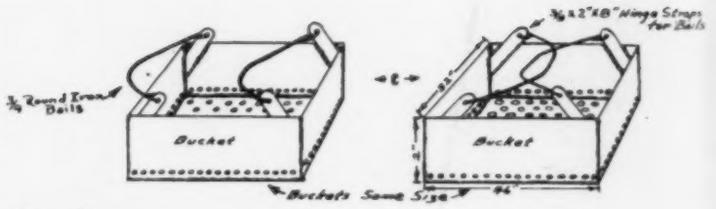
The balance of the line is being started immediately by six other prominent contractors who have pipe already on the job and are beginning to weld. These contractors are:

O. E. Dempsey Construction Company, Tulsa, Okla.
Anderson Brothers, Tulsa, Okla.
Oklahoma Contracting Company, Dallas, Tex.
C. S. Foreman Company, Kansas City, Mo.
Ray E. Smith Construction Company, El Dorado, Kan.
Sheehan Pipe Line Construction Company, Tulsa, Okla.

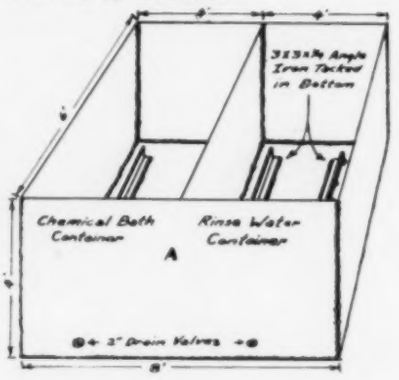
Photo courtesy Lincoln Electric Co.

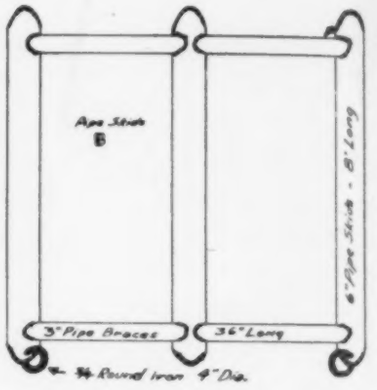
The pipe-line, which is 24 in. in diameter and the largest completely arc-welded crude oil pipe line in the world was started near the Texas-Arkansas line. Illustration (above) shows welders lining up and tacking two sections of the seamless steel tubing. Illustration (below) shows operators roll welding a section making finish welds preparatory to bell-hole tie-in welds.

Secretary Ickes in announcing contracts for the construction of the 35 million dollar line said the line would be completed and in service by Christmas. It is a tribute to the contractors that a line of this size could be completed in such a record breaking time.



CHEMICAL BATH LAYOUT





CLEANING PIPE-LINE CONNECTIONS*

Saving man-hours and metal is a mighty important contribution to our war effort. By using the metal from a scrap pile and his arc welder to construct it into a useful tank, W. R. Tierce, welding operator for the Illinois Pipe Line Company, saved 128 man-hours with his fast, new method for cleaning pipe-line connections.

The usual method of cleaning connections is to clean them with a wire brush with either gasoline or kerosene. Now maintenance men use a chemical bath which cuts down cleaning time tremendously. The connections are placed in the dipping buckets (shown in the drawing) and placed in the chemical bath section of the cleaning tank (*A*, in drawing). A fire is lighted under the tank and the connections left to boil for 5 hr.

Next, the fire is put out and the bucket withdrawn from the bath—given time to drain—and plunged five or six times into the rinse section of the tank. When cool, a few passes with a wire brush will clean connections perfectly. Then the connections are painted and placed in stock for further use.

All metal for the dip tank and dipping buckets was taken from the company's scrap pile. The tank was constructed by welding sections of old $^1/_4$-in. flat sheet tank bottoms. Bucket guides and rests on the bottom of the tank were made from 3 x 3 x $^1/_4$-in. angle iron. A 2-in. drain valve drains each compartment. Tank skids were made from 6-in. and 3-in. pipe—as shown in the drawing.

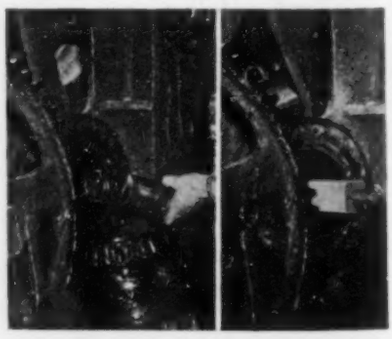
The dipping buckets were constructed also by welding $^1/_8$-in. sheet tank bottoms. Bails were made from $^3/_4$-in. round iron scrap; hinge straps from $^3/_8$ x 2 x 8-in. iron. Holes were drilled into bucket bottom for draining. Each bucket holds one ton of connections.

* From the winning entry in Hobart's Monthly Arc Welding News Contest.

The bucket and dip tank cost only $46.22 to construct including materials, labor and overhead. For comparison, the company cleaned the same amount of connections by both methods. Cleaning by wire brush and kerosene took four men six days' time or 192 hr. Cleaning with the welded chemical dip tank took four men two days or 64 hr. A single application of the new cleaning process paid for its construction.

SHAFT REPAIR

If you're from Missouri, here's picture proof of the value of arc welding for maintenance work and repairs. Left photo below shows shaft on a small diesel shovel broken about 4$^1/_2$-in. from its one end. This shaft carries the swing and travel pinion for the shovel. Although a new one could have been delivered in a week, the shovel was needed for work immediately. So a portable engine-driven arc welder was taken to the job, and the shovel was working the next day after breakdown.



Photos courtesy Hobart Brothers, Troy, Ohio

WELDING..

Tanks . . . Guns . . . Planes — and even the Ships used to transport them — are getting to our fighting fronts faster and in greater number because of welding.

Hollup Corporation, a division of National Cylinder Gas Company, is doing all it can in the 24 hours of each day to speed its output of rods and electrodes, A.C. and D.C. welding machines, "Shield-o-matic" welding apparatus, and the new Stud Welding System.

HOLLUP *products and services are helping speed war production*

"weld" protected arc electrodes, in many types and sizes, give the best results for any job.

Electric welders for A.C. or D.C. operation are available in a complete range of sizes to meet any requirement.

"Shield-o-matic"—fully automatic shielded-arc welding process which meets all code requirements.

Stud welding system for production end-welding of steel sections to metal surfaces.

HOLLUP products may help speed your output . . . *Write for literature, specifying equipment in which you are interested.*

HOLLUP CORPORATION

DIVISION OF

NATIONAL CYLINDER GAS COMPANY

205 W. WACKER DRIVE — *Offices in Principal Cities* — CHICAGO, ILLINOIS

ELECTRODE MANUFACTURING PLANTS—CHICAGO, ILL. STOCKTON, CAL. AND TORONTO, CANADA.

For repair, the broken shaft was fitted back into place and tack welded. Then deep vees were cut into crack with an acetylene torch. Build-up beads were run with 1/8-in. mild steel rod. After shaft was welded securely together, of course, the tack welds were veed out also. Shaft was turned during welding to keep welds even and to facilitate safe cooling. Very little grinding was needed on the welds. Right photo above shows completed repair.

Complete repair job for the Lakeside Gravel Co. of Bellevue, Washington, cost only $12.45. A new shaft costs $70.

WELDED SCRAPER BLADES

With the help of arc welding, scraper blades can be used on both edges. It is an easy job to turn the blades. But since the skid shoes are also worn, they will not fit the unused edge of the turned blade. Any welding operator, however, finds it easy to build up the leading edges of both skid shoes with hard facing electrodes. Job shown below is typical. Note amount of wear from finished weld beads on skid shoes. Job was performed by Norman J. Fitzer, welding operator, for the City of Miami, Fla.

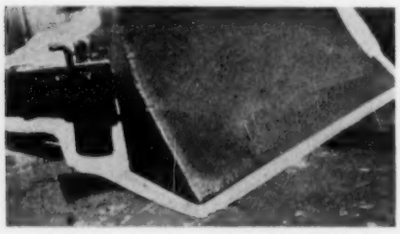


Photo courtesy Hobart Brothers Co., Troy, Ohio

WORN SHAFT REBUILT

No priority rating. Yet the worn shaft on a feeder for an Allis-Chalmers rock crusher was back in operation with a shaft as good as new after it had been repaired by arc welding. This shaft, with a 4-in. eccentric, was worn approximately 5/16 in. on each section and about 1/2 in. at the end of each bearing. Hard facing was performed with a 3/16-in. electrode. Only one bead was run on each bearing at a time to prevent warping; similar procedure was followed on the shaft. Cost to the Victoria Gravel Company of Burnet, Texas was $138.38. New shaft costs $300. Picture below, courtesy Hobart Brothers, Troy, Ohio, show shaft during welding and after machining was completed.

O.E.M. Photo by Palmer

Fort Story Coast Defense

Tracking the Target on One of Fort Story's Giant Guns

NEW BOOKLET ON A-C WELDERS

A new 8-page booklet, describing a-c welders for use with the Unionmelt process to speed industrial production, is announced by the Westinghouse Electric and Manufacturing Company.

The Westinghouse a-c welder is designed especially for use with the Unionmelt welding. These transformer welders together with Unionmelt equipment give faster continuous production at lower cost.

The new booklet describes the advantages of the a-c welder and its performance with the Unionmelt process. Several applications are listed and described, and photographs illustrate the various parts of the unit and some applications.

This process has proved particularly advantageous in speeding production in such vital defense industries as ship building and freight and tank car construction.

A copy of booklet B-3090, "Westinghouse A-C Welders for Use with the Unionmelt Process," is available from department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

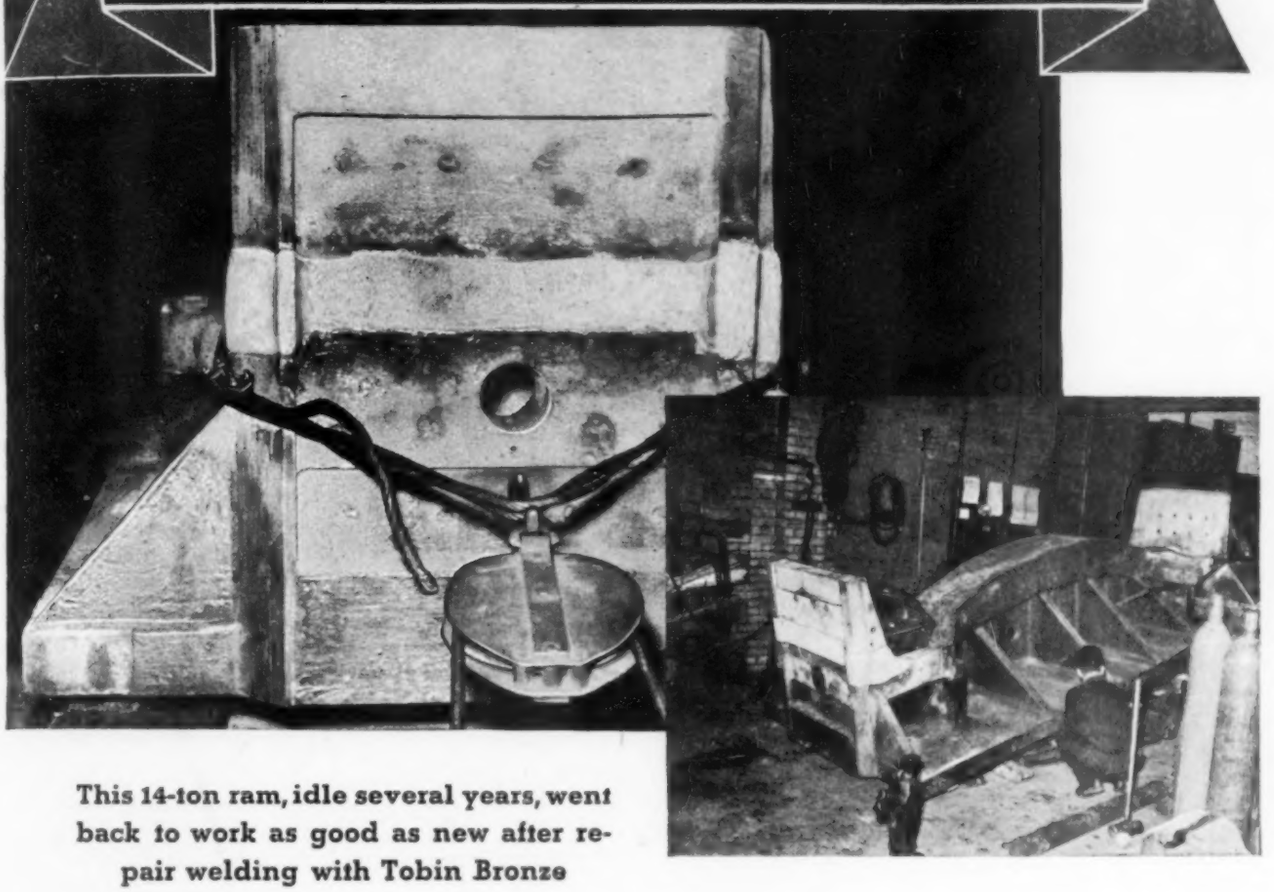
SCOTT-TARBELL CO. TO COVER NORTHERN OHIO AREA

The formation of the Scott-Tarbell Co., welding supply jobbers in Northern Ohio, is announced today. Ray Tarbell formerly was associated for a number of years with the Una Welding Co. of Cleveland and before that with the Babcock & Wilcox Corp. Ed. Scott, the other member of the firm has been and continues to be, president of The Cleveland School of Welding.

The Scott-Tarbell Co. will distribute Allis-Chalmers Co. Weld-O-Tron and Allis-Chalmers Co. alternating current welders; will represent the Victor Equipment Co. line of welding and cutting torches; Tweco Products Co. line of electrode holders, clamps, and cable connectors; Una Welding, Inc. automatic and shielded arc line of electrodes; and a complete service for welding needs, including protective equipment clothing, as well as a consulting engineering service.

The address of the new company is 2261 East 14th Street, Cleveland, Ohio.

Speeding war work through Tobin Bronze Welding!



This 14-ton ram, idle several years, went back to work as good as new after repair welding with Tobin Bronze

Rams of this size take months to manufacture and deliver. So, when this one was found coincidentally with a call from a war job for such a piece of equipment, everyone felt quite happy . . . for awhile. Inspection revealed a badly patched fracture which probably occurred many years ago.

Undismayed when it examined the ram, the Super Arc Welding Company of Detroit set out to put the equipment into first-class operating condition . . . by Tobin Bronze Welding. After three days of adjusting the parts, they started preheating and welding. Three days later, with the help of 1750 pounds of Tobin Bronze, this ram went to work on war production.

• • •

Tobin Bronze and other Anaconda Copper-Alloy Welding Rods are always "on call" for war production work.

ANACONDA
from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

NEW ELECTRODE

A new arc-welding electrode, designed to add still more speed to arc welding in war production, is announced by The Lincoln Electric Company of Cleveland.

The new electrode, designated as "Fleetweld 11," is created expressly for use with the "Fleet-Fillet" technique of arc welding, recently announced by the company. The electrode is designed to obtain maximum benefit in speed of welding from the new technique.

"Fleetweld 11" is not only a fast-flowing electrode, but it gives deeper penetration of metal into the root of the joint. It is of shielded arc type and heavily coated to exclude oxides and nitrides from the weld, thus assuring the high quality of weld metal characteristic of the shielded arc process.

In demonstration, the new electrode welded in 35 sec. a joint that required 1 min. and 17 sec. to weld with conventional electrodes and ordinary procedure.

The new electrode and the "Fleet-Fillet" technique permit up to 100% faster fillet welding, and will cut the production time on welded ships, tanks, guns and other strategic war materials.

A-C ALL-POSITION WELDING ELECTRODE

A new electrode designed specifically for all-position welding of mild steel with A.C. type welding machines has been developed by Wilson Welder and Metals Co., Inc., in the following diameters: 1/16, 3/32, 1/8 and 5/32 in. Made to fill a rapidly growing need for a high quality A.C. electrode for all-position use, the Wilson No. 530 electrode complies with all requirements of the AMERICAN WELDING SOCIETY Classification E6011, American Bureau of Shipping, Group H1G and B1G for A-C and other specifications qualifying it for use on war work.

The high quality of deposited metal of the No. 530 is fully comparable to that of the best D.C. reverse polarity all-position electrodes.

Following are physical test results made on all-weld-metal tensile specimens:

	As-Welded	Stress-Relieved
Ultimate tensile strength	70,000–75,000	65,000–70,000
Per cent elongation in 2 in.	25–30%	30–35%

An outstanding characteristic of this A.C. electrode is that average operators have no difficulty in securing good fusion and complete penetration. The finished weld deposit is quite smooth and has a uniform surface contour.

WELDERS' SAFETY CLOTHING

To protect welders against painful and dangerous exposure to molten metal sparks, American Optical Company of Southbridge, Mass., announces a completely new and wide assortment of high-grade welders' safety clothing that will keep hot sparks away from skin and normal work clothes.

A catalogue, picturing and describing each of the garments, is available, and copies will be mailed on request to welders, foremen of welding departments, safety engineers, purchasing agents, plant managers and any others interested. An authoritative treatise on chrome tanned leather clothing for welders, this catalogue is particularly valuable because it informs the welder as to the type of protective clothing he needs on any particular job.

Listed in the catalogue are overalls, all-leather pants, hot weather pants, chaps, split leg apron, one piece apron, coat, cape sleeves and bib, short jacket, welders' sleeve, spats, gloves and mittens, sleevelets and various complete protection combinations. A section of the catalogue is devoted to hints on how to break in the safety clothing to get maximum service and wear.

ELECTRONIC CONTROL FOR RESISTANCE WELDING

A new 38-page illustrated booklet, giving a simplified explanation of electronic control for resistance welding, pointing out the different kinds of resistance welding that can be done, the function of the various controls and the degree of accuracy made possible by electronic control is announced by the Westinghouse Electric and Manufacturing Company.

The various types of electronic control for resistance welding are illustrated and described. The booklet also explains what it is, what it does, and where and how it is applied. Also included in the same publication are three pages of application data on the choice and application of A.C. single-phase resistance welding control, an 8-page bulletin on fundamental electronic circuits, and a discussion of the cathode ray oscilloscope and its application to welding timers.

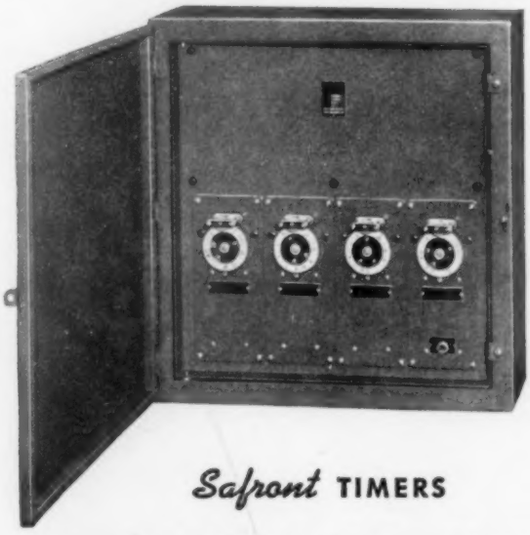
The heart of all these resistance welding controls is the ignitron tube. The development of this tube answered the long-standing problem of satisfactorily interrupting high currents at speeds of 600 operations per minute and above. Its extreme precision and dependability make possible increased production of stronger, more uniform welds of aluminum and other critical alloys.

A copy of booklet B-3102, *Westinghouse Electronic Control for Resistance Welding*, may be secured from any Westinghouse District Office.

EQUIPMENT FOR AUTOMATIC ARC WELDING WITH HEAVILY COATED STICK ELECTRODES

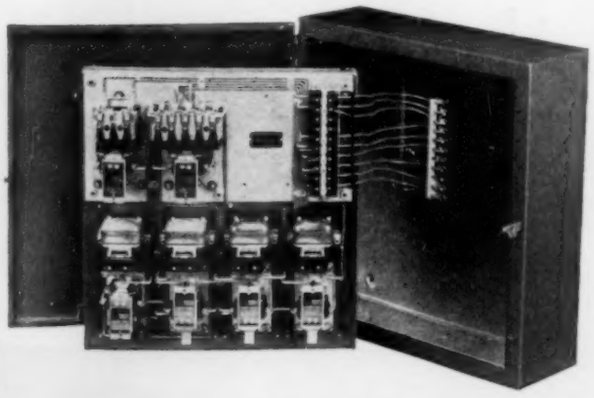
Complete equipment for automatic arc welding with heavily coated electrodes in cut lengths has been announced by the General Electric Company. The essential elements of this equipment also have been made available in order that automatic arc-welding heads originally designed for operation with thyratron-controlled coiled electrodes can be converted for successful welding with stick electrodes.

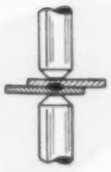
IS YOUR RESISTANCE WELDER *Automatically* CONTROLLED?



Safront TIMERS

- Square D builds 18 NEMA standard types of Safront weld and sequence timers. Unusual application conditions will be met with special construction from unit parts.
- Safront construction places all electrically energized parts behind a protective panel. Yet calibrated timer adjustments are completely accessible on panel front.
- Separate pneumatic timing devices, provided for each step of the welding cycle, are individually adjustable from 3 to 100 cycles, simply by turning a small knurled wheel.
- Safront interiors "swing out" to expose operating parts. A separable connector permits panel removal without disturbing external connections.



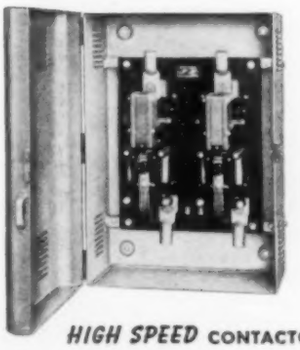


A resistance weld is made when two or more pieces of metal are clamped between copper electrodes and a high value of current is passed through them. Consistently good results depend upon application of *pressure* and *power* in a *carefully controlled sequence.*

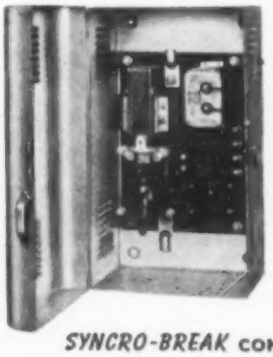
Automatic control for both pressure and power functions gives uniform welds and the highest production rates practical under existing conditions.

Square D has devoted years to the development of fully automatic control for all types of resistance welding machines.

Specify Safront Timers with Syncro-Break or High Speed contactors on your new machines. Consult our representative about the possibility of equipping old machines now in service, to improve both quality of welds and production rates.



HIGH SPEED CONTACTOR



SYNCRO-BREAK CONTACTOR

Both Syncro-Break and High Speed contactors possess unusual design features necessary for frequent making and breaking of the resistance welding transformer primary circuit.

The Syncro-Break design includes means for opening the circuit without arcing at contact tips—thus improving contact life and increasing allowable ratings. This Square D development has proved to be the solution to contactor difficulties normally experienced where operating rates are high and loads heavy.

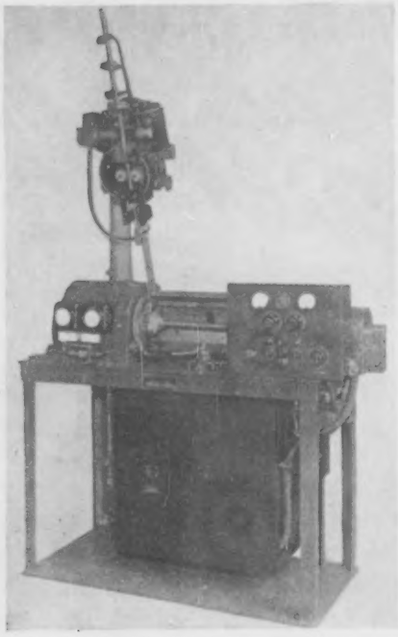
These contactors, with Safront timers, provide fully automatic control for all types of resistance welding machines.

SQUARE D COMPANY

DETROIT - MILWAUKEE - LOS ANGELES

KOLLSMAN INSTRUMENT DIVISION, ELMHURST, NEW YORK

IN CANADA: SQUARE D COMPANY CANADA LIMITED, TORONTO, ONTARIO



The equipment is particularly suited to work where one or more complete joints can be made with a single electrode, such as in the welding of shells, wheels and tubular assemblies where the starting and finishing ends of a single weld bead overlap. It has been used to make edge, lap, fillet and groove welds. Applications have included the welding of machine gun water jackets, tank wheels, ordnance shells and refrigerator parts.

The equipment is similar to that used for welding with coiled electrodes except for the electrode feed rolls and electrode guiding device. The mechanism includes a clamp for holding any standard stick electrode, and for transmitting current to the electrode. The clamp is attached to the end of a feed rod upon which two feed rolls operate to maintain the proper arc voltage through automatic thyratron control. The electrode is accurately guided to maintain the arc in a predetermined location. Limit switches govern the extremes of movement in either direction.

To operate the equipment, the welding operator inserts an electrode in the clamp, presses the START button, and the equipment strikes and maintains the arc, feeding the electrode at the proper rate to maintain the preset arc voltage. Welding continues until stopped by a limit switch, at which time the electrode clamp returns to starting position to receive a new electrode. When more than one joint is to be welded with one electrode, an additional limit switch is used for each intermediate stop.

REMOTE CONTROL UNIT

Hobart has developed a new remote control unit which is now a standard production feature of all welders offered for sale by the company. This improved control is protected fully from accidental breakage by a metal pull-out handle set over the control dial and by cushion springs on the back of the porcelain rheostat.

The new dial, it is believed, will increase weld qualities—especially welds made under modern high-speed techniques. It is well known among operators that for best results, welding heat should be increased somewhat when using coated electrodes in changing from flat position to vertical or overhead positions, and vice versa. Operators are only human, however, and with many operators there is a temptation to "get by" without changing machine adjustment because such changes involve repeated trips between work and machine.

With remote control, this condition does not exist, because it places 100 steps of fine volt-amperage adjustment right within reach of the operator's hand. The remote control unit is easily set up by using an ordinary lamp cord extension to connect it to the machine.

The large outer control dial, shown in the picture, is the field rheostat which controls the differential compounds—while the remote control unit adjusts the open circuit voltage. One thousand combinations of voltage and current are possible with this Hobart Multi-Range Dual Control Dial.

LOW PRESSURE WELDING GUN INTRODUCED

When welding brackets or clips to light gage alloy steels, light welding pressure is required in order not to deform the metal. A gun designed for such welding operations has been introduced by Progressive Welder Company, 3050 E. Outer Drive, Detroit (see Fig. 1).

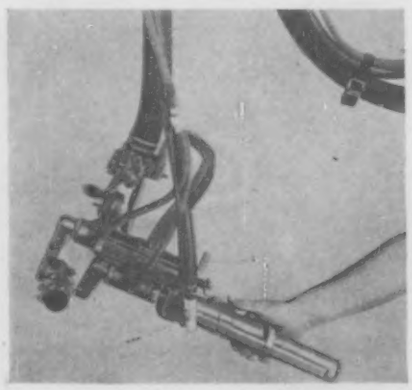


Fig. 1—Close-Up of New "Progressive" Welding Gun Designed for Spot Welding of Light Gage Alloy Steels, Where Low Pressure Is Required in Order Not to Deform the Work

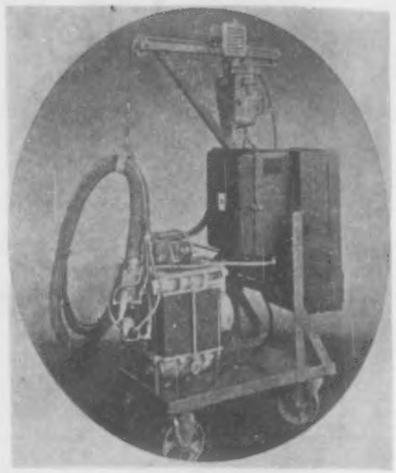


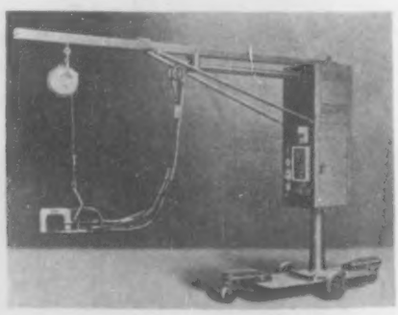
Fig. 2—The New Progressive Low-Pressure Welding Gun for Light Gage Alloys Is Available Complete with Transformer, Controls, etc.

Gun operating pressure is hydraulic with partially counterbalancing continuous air pressure. The latter also serves to automatically retract the points when hydraulic pressure is released, thereby simplifying operation.

Features of the gun include screw-adjustable stroke (up to 3 in.) to take care of a wide range of work sizes, and quick interchangeable adapters for electrodes to make the gun suitable for a wide variety of work shapes. P-H concentric kickless and highly flexible welding cables and electronic controls are used in the complete assembly which is shown in portable form in Fig. 2.

RADIAL SPOT WELDER

A radial-type gun spot welder, P-1-R, is now being offered by Sciaky Bros., 4915 W. 67th St., Chicago, in both stationary and buggy-mounted units. It is equipped with a special Sciaky welding timer and operates on single phase a.-c. 220 or 440 volts. Hydraulic pressure is supplied by a hydro-pneumatic booster, which can feed a gun able to supply a maximum electrode pressure of 1800 lb. with 90 psi. of air supply.

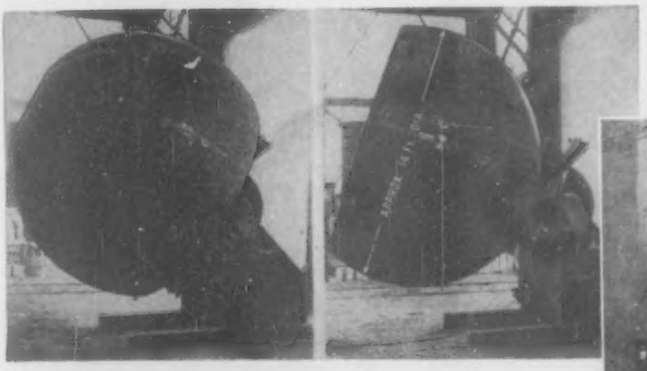


Fixed or crowded jigs can be easily reached with the portable buggy-mounted welding gun (illustrated). The maximum area reached by the stationary unit is represented by a circle of 21 ft. diameter.

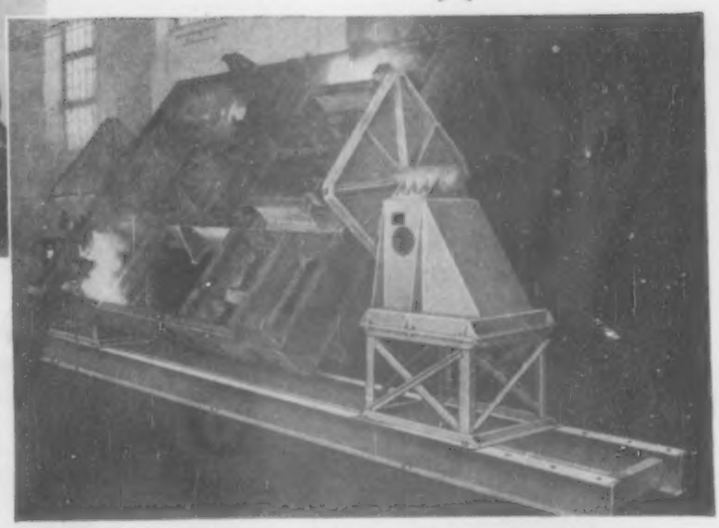
Secondary cables are thin, flexible and short; the reduction in the usual size of

Ransome. Welding Positioners for Greater Production

Left. Many-angled piece positioned for all downhand welds.
Center. Heavy machine bases are of welded construction.
Right. A complicated weldment easily handled on a positioner.



Standard positioner fitted with extension brackets for handling work larger than the table top, such as tanks, frames, etc.



Rotating Welding Fixtures consisting of motor-operated Head-stock with Tail-stock unit, handling large frame. Tail-stock is placed to accommodate objects of various lengths.

BOOTH B-102 • NATIONAL METAL SHOW • CLEVELAND • OCT. 12 through 16

Light-duty Hand-operated | 2500 lb. Cap. on Elevating Base | 3000 lb. Cap. | 3 Ton Cap. | 8 Ton Cap. | 20 Ton Cap.

INDUSTRIAL DIVISION **RANSOME MACHINERY CO.** DUNELLEN NEW JERSEY

secondary cables is made possible because of the use of fixed heavy copper bars (water-cooled) in the length of the secondary circuit.

In steady production conditions, this welder is capable of welding: corrosion-resisting steel, pickled steel, zinc-coated steel and Monel metal in thicknesses of from 0.016 in. plus 0.016 in. up to 0.064 in. plus 0.064 in. It will also weld two unequal thicknesses up to a total welded thickness of 0.500 in., provided that one of the two thicknesses does not exceed 0.040 in.

MAINTENANCE PUBLICATION

Keeping all kinds of present equipment in proper repair is not merely a patriotic duty these days. It is one of the requirements that must be done if we are to win the war in the shortest possible time. This fact is aptly expressed in "CLETRAC FACTS," new publication of The Cleveland Tractor Company, Cleveland, Ohio.

To assist Cletrac dealers in their efforts to "Keep 'em Rolling," the second issue of "CLETRAC FACTS" features five practical suggestions for maintaining Cletracs in productive service.

One suggestion explains how worn lower track wheel shafts can be restored in approximately 3 hours by building them up through welding—then grinding them down to their original diameter. Another describes the methods used to rebuild Model F grousers by cutting, then welding lengths of stock to the worn grousers. A third illustrates how diesel lower track wheels—worn to a taper—can be built up with from 3 to 5 pounds of electrode,

(*Continued on page 734*)

List of New Members

August 1 to August 31, 1942

BOSTON

Coen, Martin J. (B), 24 Lake St., Cambridge, Mass.
Couch, Alton (B), Bethlehem Steel Co., 80 Border St., E. Boston, Mass.
Kapinos, John (C), 3 Huntington Ave., Chicopee Falls, Mass.
McMullen, John G. (F), Mass. Inst. of Tech., Dormitories, Cambridge, Mass.
Van Nest, Francis H. (C), 7 Alden Rd., Marblehead, Mass.
Williams, Hugh S. (C), P. O. Box 3, Millville, Mass.

CANADA

Chambers, H. J. A. (C), Hamilton Bridge Co., 231 Bay St. No., Hamilton, Ont., Canada.
Christmas, Alan R. (C), Rudel Machinery Co., 614 St. James St. W., Montreal, Canada.
Ralley, A. G. (B), Canadian Pacific Railway, Room 900, Windsor Sta., Montreal, Canada.

CANAL ZONE

Davis, G. H. (D), P. O. Box 333, Cocoli, Canal Zone.

CANTON

Durig, L. B. (D), Tappan Stove Co., 250 Wayne St., Mansfield, Ohio.
Meyers, Meyer J. (C), 612 N. 5th St., Steubenville, Ohio.

CHICAGO

Bulaw, Adolph (B), Bulaw Welding Co., 2415 Belmont Ave., Chicago, Ill.
Dutlinger, Walter J. (D), J. T. Ryerson & Sons, Chicago, Ill.
Genotte, Francis J. (D), 534 W. Broadway, Box 415, Bradley, Ill.
Hoglund, Bruno A. (D), Roth Mfg. Co., 1600 S. Kilbourne Ave., Chicago, Ill.
Kruse, W. P. (D), 26 S. Union St., Elgin, Ill.
Towner, Milton C. (B), 54 W. Chicago Ave., Chicago, Ill.
Zack, Hans J. (B), Zack Co., 2311 Van Buren St., Chicago, Ill.

CLEVELAND

Evans, George L. (C), 13706 McElhatten Ave., Cleveland, Ohio.
Lockhart, David L. (C), Limaville, Ohio.
Noguchi, I. J. (B), 3983 E. 123rd St., Cleveland, Ohio.
Oldenkamp, Henry A. (B), % Warner & Swasey, Carnegie at E. 55th St., Cleveland, Ohio.
Polomsky, Charles G. (D), 849 E. 149th St., Cleveland, Ohio.
Szuce, John A. (C), 1779 Fulton Rd., Cleveland, Ohio.

COLUMBUS

Bonnette Lamar L. (F), Ohio State Univ., Tower Club, Columbus, Ohio.
Chaney, Roger L. (C), 136 W. California Ave., Columbus, Ohio.
Williamson, Frank (C), 211 No. Burgess Ave., Columbus, Ohio.

CONNECTICUT

Koch, L. C. (D), The Fafnir Bearing Co., New Britain, Conn.
Sproat, Ira E. (B), 54 Gorham Ave., Westport, Conn.

DETROIT

Bramlett, James B. (C), 52 E. Willis St., Detroit, Mich.
Coffin, B. R. (B), % De Sota-Warren, Chrysler Corp., Detroit, Mich.
Crawford, Howard (C), Alloy Rods Co., 9800 Belletree, Detroit, Mich.
Haines, Francis W. (B), Wolverine School of Trades, 1400 W. Fort St., Detroit, Mich.
Henst, A. Vander (C), 2455 Avon S. W., Beverly, Detroit, Mich.
Holden, Howard B. (B), 868 Lawrence Ave., Detroit, Mich.

HAWAII

Makino, Harry K. (C), 931 Coolidge St., Honolulu, T. H.
Shiroma, Yoshiharu (B), 429 N. Vineyard St., Wahiawa, Honolulu, T. H.

INDIANA

Carmichael, Burgess (B), Mouldings, Inc., 741 E. Market St., Indianapolis, Ind.
Dunn, Cecil O. (D), 1604 Louise St., Indianapolis, Ind.

LOS ANGELES

Ashman, Theodore R. (D), U. S. Navy Receiving Station, San Diego, Calif.
Yonker, Earl L. (D), 113 S. Bush St., Anaheim, Calif.

MARYLAND

Louck, Frederick F. (C), 511 Delmar Ave. Glen Burnie, Md.

MILWAUKEE

Beck, E. R. (C), Square D Co., 4041 N. Richards St., Milwaukee, Wisc.
Cart, W. B. (B), Allis-Chalmers Mfg. Co., Milwaukee, Wisc.
Krainer, Ernest (B), Allis-Chalmers Mfg. Co., Milwaukee, Wisc.
Larsen, Howard B. (C), 1628 W. Wisconsin Ave., Milwaukee, Wisc.
Lincoln, C. S. (B), Allis-Chalmers Mfg. Co., Milwaukee, Wisc.
Schumbacker, Willard (C), Allis-Chalmers Mfg. Co., Milwaukee, Wisc.
Stull, Paul (C), % Ray-O-Vac Company, Madison, Wisc.
Turay, Joseph (D), 5218 W. Uliet St., Milwaukee, Wisc.

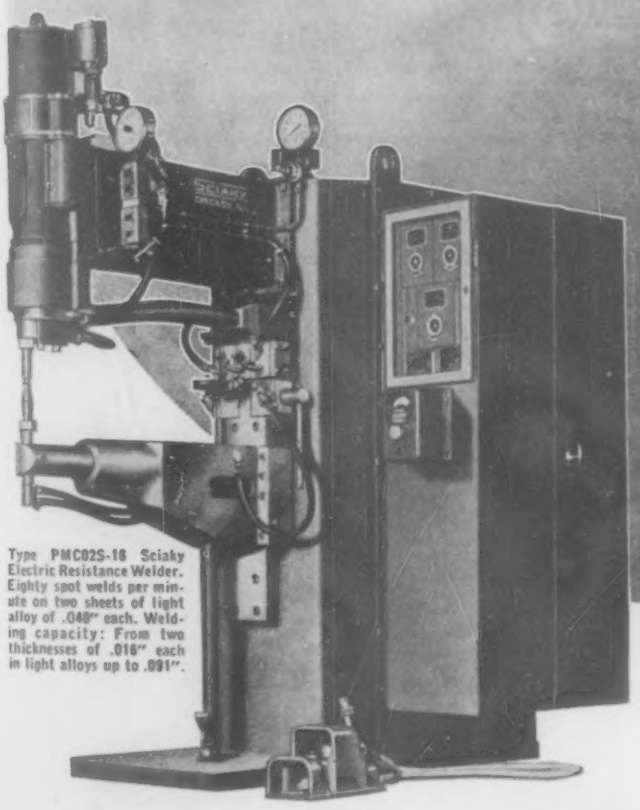
NEW YORK

Bryers, John H. (D), 128-12 Gotham Rd., So. Ozone Park, N. Y.
Dernbach, Henry E. (D), 299—8th St., Brooklyn, N. Y.
Gaug, Nicholas (D), Multi-Metal Wire Cloth Co., 1350 Garrison Ave., Bronx, N. Y.
Kirshey, John (D), 1114 Fteley Ave., Bronx, N. Y.
Morrow, J. L. (C), 280 E. 31st St., Brooklyn, N. Y.
Petersen, Ernst (D), Van Alst Metal Wks., Inc., 1233 Broadway, Long Island City, N. Y.
Prince, Leo R. (D), 1112 Metcalf Ave., Bronx, N. Y.
Reinholtz, Christian (D), 60-31 Maspeth Ave., Maspeth, L. I., N. Y.
Ryan, Leonard R. (B), 104 Adelphi St., Brooklyn, N. Y.
Zandy, Victor (C), H. K. Lorentzen, Inc., 391 Broadway, New York, N. Y.

NORTHERN NEW JERSEY

Hall, Lewis W. (D), 29 Harvey Ave., Rochelle Park, N. J.
Mathews, Arthur (D), 334—3rd St., Florence, N. J.

BUY STORED ENERGY WITH *Preheating* AND VARIABLE PRESSURE WITH *Precompression*



Type PMC02S-16 Sciaky Electric Resistance Welder. Eighty spot welds per minute on two sheets of light alloy of .048" each. Welding capacity: From two thicknesses of .016" each in light alloys up to .091".

ONLY SCIAKY CAN GIVE YOU THESE EXCLUSIVE FEATURES

WRITE FOR DESCRIPTIVE LITERATURE

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BRIGGS MFG. CO.
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NOORDUYN AVIATION, LTD.
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UNITED STATES NAVY
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SCIAKY

PROCESS ELECTRIC RESISTANCE WELDING
STORED ENERGY · VARIABLE PRESSURE
WITH PREHEATING · WITH PRECOMPRESSION

NORTHERN NEW YORK

Bunk, A. Philip (F), Ave. B & 15th St., Troy, N. Y.

NORTHWEST

Jacobson, Henry C. (D), 233 Oak Grove, Apt. 307, Minneapolis, Minn.

PHILADELPHIA

Cooper, James R. (D), 40[illegible]N. 30th St., Camden, N. J.
Dash, Edward (C), U. S. Navy Yard, Bldg. 11, Philadelphia, Pa.
Hartstein, George E. (D), 1711 Race St., Philadelphia, Pa.
Jones, Sherman B. (D), 2104 S. State St., Media, Pa.
Long, Walter R., Jr. (D), 1949 River View Rd., Bethlehem, Pa.
Von Borchers, Charles (B), Kellett Autogiro Corp., 58th St. & Grays Ave., Philadelphia, Pa.
Yocum, William F. (D), 2719 Helen St., Philadelphia, Pa.

PITTSBURGH

King, L. P., Jr. (B), 1st Ave. & Mill St., Coraopolis, Pa.
Mears, Harry A. (B), Standard Steel & Wire Co., Bolivar, Pa.

PUGET SOUND

Barr, J. B. (C), 4226—11th Ave., N. E., Seattle, Wash.
Clowe, Wayne (D), 8802 Delridge Way, Seattle, Wash.
Flohr, L. Carlos (B), Apex Sheet Metal Wks., 916—12th Ave., Seattle, Wash.
Strong, Sydney (C), 1612 Boylston Ave., Seattle, Wash.

SAN FRANCISCO

La Franco, Albert (D), 943 Kains Ave., Albany, Calif.
Leh, Alden W. (B), The Austin Co., Pittsburgh, Calif.
Massaro, Leo E. (D), 4093 Watherhouse Rd., Oakland, Calif.
Palmer, W. N. (D), 712 San Fernando Ave., Cupertino, Calif.

WASHINGTON, D. C.

Hetherington, C. R. (C), Naval Gun Factory, Desk K, Washington, D. C

WESTERN NEW YORK

Knapp, Russell (D), 228 Bank St., Batavia, N. Y.
Sargeant, John F. (D), 43 No. Main St., Honeoye Falls, N. Y.

YORK—CENTRAL PENNA.

Bauer, William C. (C), 335 Harding Court, York, Pa.

NOT IN SECTIONS

Bolchoz, T. R., Jr. (B), Box 39, Cosgrove Ave., Charleston, S. C.
Bolton, Chas. H., Jr. (C), Tampa Shipbldg. Co., Tampa, Fla.
Brill, P. B. (B), Tampa Shipbldg. Co., Tampa, Fla.
Brothers, Charles M. (C), 1435 S. E. Lafayette St., Portland, Ore.
Brown, J. A. (C), Tampa Shipbldg. Co., Tampa, Fla.
Copeland, Wm. H. (C), Tampa Shipbldg. Co., Tampa, Fla.
D'Andrea, A. Ralph (B), Industrial School of Welding, 61 Broadway, Newburgh, N. Y.
Doig, Joseph (D), 133—4th Ave., So. Charleston, W. Va.
Greenway, H. Lee (B), 409 W. Arctic St., Folly Beach, S. C.
Ilderton, Augustus A. (B), 13 Seminole St., Charleston, S. C.
Lynch, J. W. (C), Tampa Shipbldg. Co., Tampa, Fla.
Merricks, Max P. (B), P. O. Box 2, Williamson, W. Va.
Morrison, R. E. (B), Kentucky Metal Prods. Co., 3104 So. Preston St., Louisville, Ky.
Painter, Jack (C), Tampa Shipbldg. Co., Tampa, Fla.
Peters, R. I. (C), Tampa Shipbldg. Co., Tampa, Fla.
Powers, M. W. (B), Tampa Shipbldg. Co., Tampa, Fla.
Ronnfeldt, Emil P. (C), 1115 No. 25th St., Lincoln, Nebr.
Thompson, Jeffrey (C), 99 Portland Ave., Old Orchard, Me.
Thompson, William L. (B), 1317 Oklahoma Ave., Woodward, Okla.
Wells, Pargus (D), Jeffersonville Boat & Mach. Co., Jeffersonville, Ind.
Winter, C. Melville (C), Tampa Shipbldg. Co., Tampa, Fla.

SECTION ACTIVITIES

CHICAGO

The first meeting of the new season was held on Friday, September 18th at the Electric Club Auditorium. A dinner at the Ford-Hopkins Restaurant, preceded the meeting, as did also a movie, entitled "The North Circle Trail of Glacier National Park" shown through the courtesy of Great Northern Railroad Co.

Mr. Arthur J. Raymo, Supervisor of Welding, Baldwin Locomotive Works, the speaker at the meeting, spoke on "Current Application of Arc Welding to Railroad Transportation Equipment."

COLUMBUS

The August meeting of the Ohio State University Student Branch of the Columbus Section of the AMERICAN WELDING SOCIETY was held August 6, 1942, at the Social Administration Building auditorium on the campus with Clarence Shultheis, president, presiding.

W. J. Mauer, Jr., of The Linde Air Products Company, addressed the group on the characteristics and uses of Unionmelt, using movies and slides as illustrations. Walter Hendricks, a senior member of the Student Branch, reported on the Engineers Council and the Engineers Picnic.

DETROIT

The first meeting of the season was held on September 4th at Rackham Educational Memorial Building. Mr. W. D. Millington, Engineer in Charge of Tools, Tank Hull Division, Cadillac Motor Car Company, spoke on the subject, "Design of Arc-Welded Joints." Mr. Millington has had a wealth of experience in the design of tools and fixtures in automotive sheet metal and body framing. Therefore, his talk was of special interest.

INDIANA

The September meeting held on the 18th at the Antlers Hotel, Indianapolis, was preceded by a dinner, followed by two short sound motion pictures, entitled, "Laying Another Submarine Cable," and "Rubber Insulated Cable."

The main event of the evening was a talk by Mr. E. W. P. Smith, Consulting Engineer, The Lincoln Electric Company, who spoke on "Inspection of Welds and Qualification of Operators."

MARYLAND

The Maryland Section is planning an educational program on welding and related processes. Subjects will be presented by men of outstanding knowledge. Schedule of dates and lectures is given below. The lecture course has been prepared for the benefit of engineers, designers, draftsmen, and supervisors of weldments. Each lecture will occupy two hours and a fee of $20.00 is being charged to those attending the lectures, some of which may be returned, if funds permit.

Oct. 6, 1942—"The Fundamentals of Welding Metallurgy as Applied Principally to Carbon Steel," by Bela Ronay, Sen. Weld. Engineer, U.S.N., E.E.S.

Oct. 20, 1942—"The Fundamentals of Welding Procedure," by Dr. John Miller, Reid Avery Company.

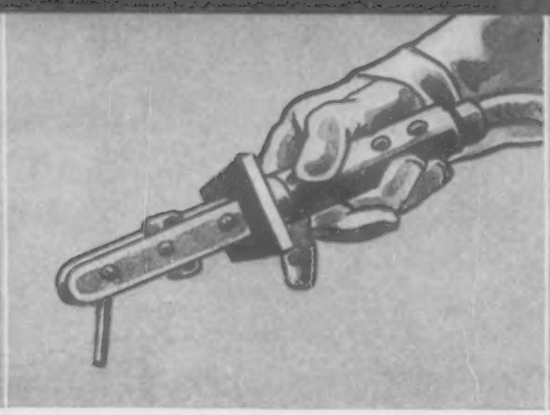
Nov. 3, 1942—"The Fundamentals of Designing for Welded Construction," by F. L. Plummer, Chief Research Engr., Hammond Iron Works.

Nov. 17, 1942—"Stress Consideration in Welding and Design of Welding Methods for Stress Relief," by D. Hertog, Lt. Comdr. U.S.N.R., Professor Harvard University.

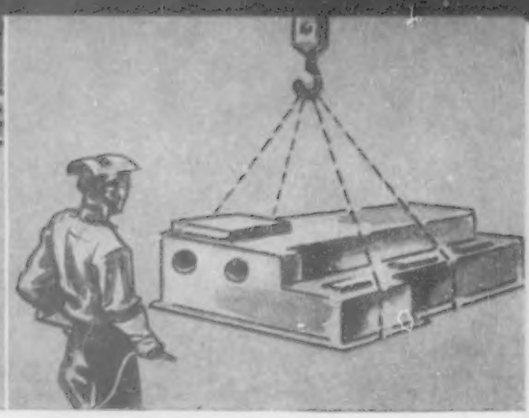
Dec. 1, 1942—(*a*) "Types of Electrodes and Their Uses," by J. H. Humberstone, Metallurgist, Arcrods Corp. (*b*) "Sources of Power for Welding Operations," by M. W. Brewster, Welding Engr., Philadelphia, Pa.

Dec. 15, 1942—"The Use of Welding

1. Deposition rates for the larger downhand rods are frequently more than double those of the smaller, all-position types.



2. A minimum of stub end losses because of maximum use of the electrode can effect savings of as much as 7%.



3. Overhead crane service and the attendant hazards to safety are reduced to a minimum when positioning is used.

POSITIONED WELDING *with*

DOWNHAND ELECTRODES SPEEDS PRODUCTION

TIME SAVINGS on welding operations have been estimated as high as 50% when downhand positioning is used. Many factors contribute to this, including faster welding because of the more rapid deposition rate of downhand electrodes and the easier handling and maneuverability of the work.

Other shop operations are accelerated also, as the use of cranes and additional men in handling the weldment are required only for the initial set-up.

Then too, a positioned weld is a *better* weld as downhand electrodes provide metal having superior physical properties and assure neater, cleaner deposits.

METAL & THERMIT CORPORATION

120 BROADWAY, NEW YORK, N. Y.

Specialists in welding for nearly 40 years. Manufacturers of Murex Electrodes for arc welding and of Thermit for repair and fabrication of heavy parts.

ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO

MUREX

ARC WELDING ELECTRODES

Symbols," by Arthur Wynn. "Testing of Welds," by Bela Ronay.

Jan. 5, 1943—(*a*) "Design and Use of Joints Fabricated by Automatic Metallic and Carbon Arc Welding," by R. F. Wyer, General Electric Co. (*b*) "Thermit Welded Joints," by J. H. Deppeler, Chief Engr., Metal & Thermit Corp.

Jan. 19, 1943—(*a*) "Design and Use of Brazed Joints," by Leo Edelson, Development Engineer, New York. (*b*) "Design and Use of Electric Resistance Welded Joints," by P. H. Merriman, Glenn L. Martin Co.

Feb. 2, 1943—"The Use of O-A Cutting Flame Hardening, Softening and Descaling," by T. J. Ward, Jr., Lt. (jg. U.S.N.R.). "The Unionmelt Process."

Feb. 16, 1943—(*a*) "Inspection of Welds and of Operators of Navy Dept.," by H. Hiemke, Sen. Weld. Eng., Bureau of Ships. (*b*) "Interpretation of Commercial Codes and Specifications," by L. M. Dalcher, Asst. Tech. Sec., AMERICAN WELDING SOCIETY.

LOS ANGELES

The following is a tentative program of meetings of the Los Angeles Section for the coming year.

September—General Electric color picture on welding.
October—Shipbuilding.
November—Resistance Welding.
December—Dinner Dance.
January—Welding Techniques of "Plurimelt" in Alloy Steel
February—Training the Operator.
March—Resistance Brazing.
April—Metallurgy of Welding.
May—Open.
June—Welding Research in Aircraft.

NEW YORK

At a meeting of the Executive Committee held on August 5th, the following committee appointments were made:

Program Committee: Merritt Smith, Chairman, E. Vom Steeg, Jr., A. K. Seemann, E. A. Roper.

Membership Committee: E. A. Kerbey, Chairman, G. Schneider, W. Spraragen.

Finance Committee: W. A. Howard, Chairman, G. Schneider, G. Sykes.

Technical Committee: H. R. Morrison, Chairman, O. T. Barnett, C. Kandel.

Reception and Entertainment: R. E. Bedworth, Chairman, E. Vom Steeg, Jr., J. G. Magrath.

It was voted not to have a lecture course this season.

The following is a tentative schedule for the regular meetings of the Section for the coming season. All meetings on Tuesdays.

Oct. 6—A.W.S. meeting on conservation.
Nov. 17—Joint meeting with A.S.M.E.
Dec. 8—A.W.S. meeting.
Jan. 12—Joint meeting with Naval Architects and Marine Engineers.
Feb. 9—A.W.S. meeting.
Mar. 9—Joint meeting with A.S.C.E.
Apr. 13—A.W.S. meeting.
May 11—A.W.S. meeting.

NORTHERN NEW YORK

All six parts of the General Electric training film, "The Inside of Arc Welding," were shown to a "full house" in the Chemistry Building Auditorium, Union College, at a special meeting August 6th. The six reels of this film are each complete in itself and were designed to be shown separately, a week or more apart, as a regular part of a training program. Therefore, for the sake of emphasis and good training, some repetitions do exist. This is particularly noticeable when the films are shown one right after the other, all in the same evening, as above. It was found helpful to include a 15- or 20-minute discussion period in the middle of the showing to help counteract the repetition in the six separate reels. It is suggested that in many cases the showing of four parts would be enough for the average audience. The remaining two parts could be described by the master of ceremonies and then shown to any of the group who were especially interested. In any case, it is highly desirable to explain the reason for the repetition before any of the films are shown. When this has been done, no serious objections or critieisms have been received and interest has been well sustained throughout the showing.

PHILADELPHIA

The following is a schedule of meetings for 1942-1943.

October 19, 1942—Building Liberty Ships.
November 16, 1942—Stress Distribution.
January 14, 1943—Welding in Aircraft Production.
February 15, 1943—Welding in the Steel Casting Industry (Joint meeting with the Foundrymen's Assn.)
March 15, 1943—Structural Design for Welding.
April 19, 1943—Gas Welding and Cutting.

Meetings are held at the Engineers' Club, 1317 Spruce Street, Philadelphia, at 8:00 P.M.

ST. LOUIS

Scheduled for the September 11th meeting of the St. Louis Section was the General Electric film for the training of welding operators, entitled "Inside of Arc Welding."

Slides on "Conservation of Electrodes" were also shown with comments by Mr. N. M. Voorhies and Mr. J. A. Spencer, arc welding specialists, General Electric Co.

SAN FRANCISCO

The August meeting of the AMERICAN WELDING SOCIETY, San Francisco Section, was held at the Athens Club, Oakland Calif., on Friday, August 28, 1942.

There were approximately 75 members and guests in attendance.

The first part of the meeting was devoted to a very interesting and enlightening talk by Mr. C. P. Miller of the Engineering Department of the Standard Oil Company on the subject of "Present Day Welding in the Petroleum Industry." The manifold problems of this important industry were brought to light and openly discussed. All those present felt they had gleaned a great deal from Mr. Miller's excellent talk.

The latter part of the program was devoted to a discussion, illustrated by slides on "X-Ray in Industry." This part of the meeting was presided over by Mr. E. W. Philleo, Manager of General Electric Radio Corporation of California. This portion of the meeting was especially interesting to those of us who had never seen what the inside of a weld looked like.

WASHINGTON, D. C.

The following are the newly elected officers of the Washington, D. C., Section:

Chairman, E. Brooker, Ordnance Dept., U. S. Army; *Vice-Chairman*, Wm. E. McKenzie, U. S. Naval Gun Factory; *Secretary*, Harry L. Ingram, Jr., Air Reduction Sales Co.; *Treasurer*, Robert F. Wood, Wm. M. Corse Chemical & Met. Eng.

Executive Committee: (2 years) R. B. Swope, B. J. Brugge, J. D. Bert, S. W. Trainer, W. B. Bunn, Jr., A. G. Bissell; (1 year) W. A. Lubbers, L. H. Fawcett.

Employment Service Bulletin

SERVICES AVAILABLE

A-430. Welding Production Manager. 30 years practical experience in both electric and Acetylene Welding. Built up the largest production welding business in this country, which also did most of the large outside welding contracts. Retired in good health. 55 years of age.

A-443. Welding Engineer: Experience through shop—Graduate Engineer with metallurgy background; experience in flow of materials for production fabrication on ferrous and non-ferrous metals; setting up new designs, layout and estimating costs. Formerly with Navy department as research welding engineer. Production experience on all types of resistance welding, automatic electric welding equipment, automatic gas cutting and welding; plus, experience with X-ray, all types of welding codes, training and supervision of welders. Experience covers welding in shipbuilding, pressure tanks and industrial plants.

MAINTENANCE PUBLICATION

(*Continued from page 730*)

then the face ground down to proper size. The fourth and fifth suggestions concern methods of rehabilitating FD lower track wheels by restoring the bead on wheels, using a home-made support to speed up the work; and, how drive sprockets can be built up to their original contour.

The type of welding electrode used to obtain the most satisfactory and economical results, is recommended for each of the above jobs.